



Co-Designing Educational Robotic Pet Concepts with Animal Welfare Educators and Children

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Abstract

Animal welfare education could greatly benefit from customised robots to help children learn about pets and their behaviour, and thereby promote positive, safe child-pet interactions. To this end, we ran co-design workshops with animal welfare educators and children to identify key requirements for robotic pets from their perspectives. Our findings encompass a zoomorphic robot's appearance, behaviour, and features, as well as concepts for a narrative surrounding the robot. Through comparing and contrasting the two groups, we find the importance of: negative reactions to undesirable behaviour from children; using the facial features and tail to provide cues signalling an animal's internal state; and a natural, furry appearance and texture. We also contribute some novel activities for co-design with children, including branching storyboards inspired by thematic apperception tests and interactive narratives, and reflect on some of the key design challenges of achieving consensus between the groups, despite much overlap in their design concepts.

Keywords Animal welfare education · Child-robot interaction · Zoomorphic robots

1 Introduction

Animals, particularly pets, can be a key aspect of children's lives. Around 70% of children in the UK grow up with pets as part of their families [1], and 85% of UK children self-describe as animal lovers [2]. Fortunately, even brief interactions with animals can have a calming effect on children

[3] and, in the long term, pets can have benefits for children's cognitive, social, and emotional development [4, 5].

However, psychological, behavioural, and environmental factors can lead to negative child-animal interactions, including intentional harm to animals, unintentional harm, and neglect [6, 7]. This can harm an animal's welfare, that is, have a negative impact on an animal's physical and/or mental well-being. A child can also be harmed physically when an animal feels the need to defend itself or harmed psychologically as a result of the interaction, which can have long-lasting social and psychological effects. For example, children who have been bitten by a dog may have to deal with not only physical injuries but also psychological consequences that affect their quality of life, including an intense fear of dogs, post-traumatic stress disorder, anxiety, and avoidance behaviours [8, 9]. Similarly, children who have witnessed harm to an animal have higher rates of internalising symptoms, such as anxiety and depression, and externalising symptoms, such as aggressive and antisocial behaviour [10].

With the dual goal of improving animal welfare and safeguarding children's well-being in mind, organisations like Societies for the Prevention of Cruelty to Animals target some of the psychological risk factors, like poor knowledge, attitudes, and beliefs about animals, through running animal

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welfare education (AWE) programmes. AWE teaches children about the concept of animal welfare and the importance of supporting positive animal welfare [11, 12]. Furthermore, AWE tries to equip children to facilitate good animal welfare, aiming to educate and inspire children to treat animals with kindness and respect [11, 13]. Programmes can target range of animals, including wild animals and farm animals, but a very common topic is pet animals, usually domestic mammals, which is our focus use case in this research.

The majority of AWE programmes do not use live animals in their programmes [14]. While a live animal is a strong motivator for children to engage with an educational intervention [15] and it allows children to practise skills [16], there are concerns about hygiene, with risks of allergies, transmission of zoonotic diseases, and the chance of animals urinating and defecating in inappropriate areas [17, 18]. There are also safety concerns, as children may be scratched or bitten if the interaction goes negatively [19]. Finally, and possibly most importantly, the animals' welfare is at risk. Animals involved in AWE are often being exposed to a new environment and large groups of new people, including children who can be over-excited and do not know how to interact appropriately with animals. Even if no physical harm occurs, animals' stress levels can be raised [20]. As a result, AWE interventions have to simulate interactions with animals using videos, imaginative exercises, or a stand-in, like a stuffed toy [14].

An organisation we have worked closely with, the Scottish SPCA, are expanding their tools and embracing technology, namely zoomorphic robots. A robot has many benefits as an educational tool compared to traditional pen-and-paper tools, stuffed toys, or web-based activities because it allows children to physically interact with it and can provide autonomous behaviours [21]. However, in informal discussions, animal welfare educators had expressed their dissatisfaction with existing zoomorphic robots. They explained that commercially available zoomorphic robots are not easy to incorporate into AWE programmes. For example, zoomorphic robots that have been used with elderly care home residents, like Paro or Ageless Innovation's Joy for All cat, can only move some limbs and cannot move around on their own [22]. Other zoomorphic robots with extensive actuation and functionality are also not appropriate for AWE because the majority are created as entertainment products. For example, the latest model of Aibo has 22 degrees-of-freedom, but promotional material shows that this impressive actuation is mostly used so that Aibo can perform tricks [23]. Due to these limitations in form and behaviour, current zoomorphic robots do not help animal welfare educators to convey key messages about animal sentience, emotions, and appropriate actions around animals.

Free-form, unstructured interaction with a zoomorphic robot is unlikely to facilitate educational goals, but one potential structure for an educational intervention is to combine the robot with an interactive narrative. Interactive narratives are a form of storytelling where the storyline is not fixed in advance and can change in response to actions and decisions by the user [24]. The goal of such narratives is to give the user a sense of affectance—that their actions have an impact on the direction or outcome of the story. One animal welfare educator we had spoken to previously described the goal of AWE as teaching children that “actions have consequences” when it comes to animals. Based on this alignment in goals, interactive narratives, if designed appropriately, could be an effective tool for AWE.

Therefore, the goal of this research was to inform the design of a zoomorphic robot that could be used in an animal welfare education intervention about pets through co-designing concepts with the key stakeholders: animal welfare educators and children. Design input from educators can help facilitate desired learning outcomes [11, 25, 26]. Furthermore, we recognise the importance of involving children in research that affects them [27, 28]. To facilitate input from both groups, we conducted a co-design workshop with 11 animal welfare educators and another with 24 8–11-year-old children. We discussed the participants' perspectives on AWE, interactive narratives, and robotics before gathering feedback on two existing zoomorphic robots. We then guided them to design a pet robot for AWE and describe stories around it. We qualitatively analysed the data, comparing and contrasting the two groups, to provide insight into the design of a zoomorphic robot and narrative for AWE.

This paper provides two key contributions for the field of zoomorphic robot design. The first contribution concerns design insights for the appearance, behaviour, and features of robotic pets and the narratives that could surround them from the perspective of children and animal welfare experts. Few works have focused on stakeholders' design requirements for zoomorphic robots: Collins et al. [29] studied ten participants' preferences for a zoomorphic robot for adults with depression. This is despite some findings suggesting a preference for zoomorphic robots over humanoid robots in certain domains [22, 30–32]. This work is the first we know of to seek the perspectives of animal welfare educators and children alike in the design of zoomorphic robots. The animal welfare educators provided a novel perspective through a focus not on entertainment but on education, in particular through designing for realistic animal-like interactions that convey the depth of an animal's sentient existence. While AWE is a specific use case for a zoomorphic robot, there are other situations where similar reasons prevent or restrict the use of live animals, like in hospital settings and the broader

school setting. Subsequently, the design insights from this work could be applied by the designers of other zoomorphic sociorobots, be they for children or adults, especially where an educational aspect is desirable.

The second contribution concerns the co-design methodology and tools for doing this with primary-school-aged children and educators. We developed a methodology for co-design workshops suitable for designing zoomorphic robots, including a structure and materials to prompt the combination of animal and robotic elements in designs. Furthermore, certain materials developed for the children's workshop, like the brainstorming of attributes based on senses and the branching storyboard with integrated prompts, could be applied in future co-design work with children. This work continues in the vein of Newbutt et al. [33] and Elloumi et al. [26] by involving both children and educators to develop robots for education. It expands on these works by using two co-design workshops with similar structure and activities to allow for direct comparison between the two groups. This comparing and contrasting helped us to identify common ground to build on and ways to navigate the different priorities. A similar methodology could be employed by other researchers investigating the design of robots for education or even non-technological educational interventions.

2 Background

2.1 Robotics in Education

Any tool for AWE needs to be informative and engaging; 85% of animal welfare educators agreed running fun, interactive sessions that ensure active learner participation and engagement is one of the most critical components for intervention success [11]. Interventions that have incorporated activities like crafts, storytelling, and serious games have successfully improved children's knowledge, attitudes, and beliefs about animals [34–36]. Excluding animals, robots are one of the richest tools for AWE; they can facilitate displays of animal behaviour and responsive, embodied interactions, highlighting to children how their actions affect the situation.

Robots can fill a variety of roles in educational interventions [37], but here we focus on robots that deliver the learning experience through social interaction [21], as opposed to construction kits [38]. The Scottish SPCA has used a robotic kit that small groups of 8–11-year-old children build and code to prompt them to think about similarities between robots' and animals' senses and decision-making processes [39]. However, despite high engagement from the children, educators have expressed some challenges with keeping the

groups focused on animal minds because the robots do not realistically simulate animals, in form or behaviour.

Social robots have been shown to have a positive impact on motivation [40, 41] and engagement [41, 42] in educational tasks, which can contribute to improved task performance [21, 40–42]. Physically embodied robots also improve task performance [41] and enjoyment [43] over virtually embodied robots.

Common interaction paradigms used in education position the robot as a teacher, tutor, peer, or novice [21]. Although these are appropriate for humanoid robots, they do not easily fit a zoomorphic robot. Instead, a more appropriate approach may be constructionist learning, where children can explore, make hypotheses, and validate their beliefs via experimentation [44], or experiential learning, where the robot is a safe substitute with which to practice skills [45].

2.2 Interactive Narratives

Interactive narratives aim to immerse the user in the story so that they believe they are a key part of the story and their actions can have a significant impact on its direction [24]. An early example of interactive narratives is the choose-your-own-adventure novel where the reader's choices made in response to events in the story could lead to different endings. Similar ideas have been used in role-playing and video games where the player's choice on, e.g., which character to befriend will lead to different story beats, customising the experience to each individual. Interactive narratives have been used to encourage users to empathise with characters [46] and consider appropriate courses of action, such as in anti-bullying education [47]. Therefore, interactive narratives are promising for AWE, depending on appropriate narrative framing and story beats, so that children can connect their actions with consequences.

2.3 Co-Design

Co-design aims to engage users in the design of systems, give them agency in the design process, and encourage active contribution to the design [48]. Druin [49] outlines four different roles children can play in the design of new technology: user, tester, informant, and design partner. Children likely take a variety of roles during a co-design workshop, but mainly act as informants and design partners. Co-design has been used successfully with a variety of user groups, including children [28, 50]. With children, co-design techniques have been used to develop robots for creativity [28], math tutoring [26], support in a special educational needs school [33], anti-bullying interventions [51], pain management [30, 52], and ethical reflection [53]. These

works have mostly been with children aged between six and fourteen, which fits our target age group.

2.3.1 Designing with Educators and Children for Similar Topics

Previous work has involved close collaboration between researchers and animal welfare charities to reach consensus on target areas [11], produce practical guides for professionals [54, 55], and to design and evaluate AWE interventions [34, 56, 57]. Through these collaborations, researchers can be confident the interventions designed meet the needs of animal welfare educators and will successfully effect change in knowledge and attitudes [34, 56]. Researchers have also involved schoolteachers in the design process to ensure interventions are acceptable to the education community [25], but, so far, children have not been directly involved in the design process for school-based AWE.

However, children have been involved in the design of technologies and education related to animals and their well-being. In one work by Pons and Jaen [58], a set of children designed technology-mediated games for animals and humans to play together, with post-activity questions prompting the child to consider how the game might contribute to an animal getting exercise and learning. Similarly, children in the workshops organised by Hirskyj-Douglas et al. [59] designed animal-involved technologies for zoo animals that were meant to be welfare-enriching. In both of these works, the co-design process itself served an educational purpose, with children prompted to reflect on the needs of animals and their interactions with animals.

Children have also been involved in the design of robotics for educational settings and tasks, usually in conjunction with teachers. For example, Elloumi et al. [26] conducted focus groups with teachers and children to learn requirements for a social robot in mathematics education, finding some overlap between the groups. Newbutt et al. [33] sought input from autistic students and teachers to develop a robot for the school, with teachers suggesting changes to an idea developed following focus groups with students.

2.3.2 Tools and Approaches

Co-design encompasses a range of tools and approaches to engage users in the design process. Below we review a selection of tools used in the workshops, paying particular attention to their suitability for use with children.

2.3.2.1 Personas Personas have been used in co-design for HRI with user groups like older adults (e.g., [60, 61]) because they create engagement with discussions and allow participants to share personal experience in a removed way.

There is limited work using personas to engage children during co-design, but we suggest that children in our age range (8–11 years old) are likely to engage well with them due to a familiarity with perspective-taking during imaginative play.

2.3.2.2 Demonstrations Demonstrations are often used in co-design for HRI (e.g., [30, 33]) to help participants to see what technology currently exists as a springboard for their later designs, since robotics is often a novel technology to many participants [62]. Demonstrations can also help participants to provide more concrete feedback on the use of robots for the proposed application [63]. Children can often come up with fantastical ideas, which is part of the benefit of involving them in co-design [64], but demonstrations where children can interact with the robot and ask questions can help them to learn about the functionality of robots, give them a better sense of the design space, and ground their designs [30, 65–67].

2.3.2.3 Brainstorming Brainstorming is a commonly used tool in co-design to facilitate idea generation [26, 51]. Sanoubari et al. [51] used three brainstorming prompts on appearance, behaviour, and name for a ‘student robot’ prior to children starting the sketching portion of the design task to break the task down into smaller, more manageable chunks, which can help children with idea generation [68].

2.3.2.4 Draw-and-Write The draw-and-write method is generally viewed as an enjoyable, non-threatening way for children to communicate information without the need from them to immediately verbalise their thoughts [69, 70] and has been used to elicit ideas and input from children on a range of topics. Since the balance of drawing and writing can be adapted by each participant, it reduces the demand on participants’ language skills and is inclusive of those with varying verbal comprehension and communication skills [71]. Therefore, draw-and-write is particularly appropriate for a workshop with a range of ages. Sketching and annotations are also commonly used in co-design workshops with adults [61].

2.3.2.5 Storyboards Storyboards are a classic tool used in co-design, especially with children and adolescents. They both elicit and document ideas, and in HRI can be used

to understand how participants envision interactions with robots [51, 72, 73].

3 Methods

3.1 Workshops

The workshops were designed to mirror each other in content and structure, but activities were modified to be suitable for each group and probe relevant experience. As suggested by Arevalo Arboleda et al. [62], workshops were conducted with the children and educators separately to enable both groups to express their perspective without influence from the other, as well as to accommodate the different activities. All materials were anonymous in an attempt to lessen participants' perceived pressure to respond in a 'favourable' way. The materials are available online.¹

Table 1 Workshop phases and activities

Phase	Activities		Duration
	Educators	Children	
Introduction	Introduction to research aims and key terms	Introduction to research aims and key terms	10–15 mins
Discussion of AWE, robotics, and interactive narratives	Identification of AWE goals; Discussion of personas; Thoughts on robotics for AWE; Impressions of interactive narratives	Self-rated knowledge of animal welfare and perceived importance of AWE; Discussion of personas; Thoughts on robotics for AWE; Impressions of interactive narratives	20–30 mins
Demonstrations	Demonstrations of MiRo and Qoobo; Feedback on robots	Demonstrations of MiRo and Qoobo; Feedback on robots	25–35 mins
Design	Draw-and-write; Discussion of narrative ideas	Brainstorming on attributes of pets; Draw-and-write; Branching storyboards	25–35 mins
Feedback	Presentation of ideas to group; Plenary discussion; Thank you and goodbyes	Presentation of ideas to group; Voting on favorite robot; Thank you and goodbyes	25–30 mins

¹ https://osf.io/zd89e/?view_only=fd944f3a0f3a4da08ee31e8ae6749f66.

3.1.1 Participants

Eleven educators took part in the first workshop (10 female, 1 male). Participants were recruited through partnership with the Scottish SPCA. All participants were part of the charity's Education Team, which is responsible for developing and delivering animal welfare programs to the public. Two participants had 1 year of experience or less, seven had 3–5 years, and two had 10+ years of experience in AWE. On average, they had 4.9 years of experience in AWE ($SD = 3.4$ years).

Twenty-four children from a school on the outskirts of Edinburgh took part in the second workshop (12 female, 12 male). The group was formed of three consecutive year groups from the school, so the children ranged in age from 8 years 9 months to 11 years 5 months ($M = 10$ years 4 months, $SD = 10$ months). Of the 24 children, 17 owned pets. Dogs were the most common pet (13 owners), followed by cats and hamsters (6 owners each) and fish (4 owners). Ten of the 17 pet owners had more than one type of pet.

3.1.2 Setup

The research protocol received ethical approval from the University of Edinburgh School of Informatics. Educators, children, and guardians received information sheets before the study and signed physical consent forms.

The educators' workshop lasted 2.5 hrs and took place at the charity's headquarters. The discussions were held in two small groups, each of which was run by a researcher. The third researcher facilitated the running of the workshop and took additional notes.

The children's workshop lasted 2.5 hrs (1 hr 50 mins of activities and two breaks) and took place at the university. The discussions happened in five small groups of four or five children (suggested to be the optimal size for focus groups with children [74]), each led by a researcher. Two other researchers facilitated the workshop, and the children were accompanied by three school staff who assisted when necessary, such as helping a younger child with writing.

3.1.3 Procedure

The two workshops followed the same structure: an introduction from the researchers; background discussion on AWE, robotics, and interactive narratives; demonstrations of two zoomorphic robots, MiRo and Qoobo, and participant feedback on the robots; a design session; and a plenary feedback session. The overall structure and breakdown of activities is shown in Table 1.

3.1.3.1 Introduction We explained the aims of the workshop, key terms, like zoomorphic robot and interactive narrative, and the target intervention group: mainstream schoolchildren between 8 and 12 years old learning about pets.

3.1.3.2 Discussion of AWE, Robotics, and Interactive Narratives The first aspect we discussed was the background of and need for AWE. The children started by rating their own knowledge about animal welfare and their perception of the importance of learning about animal welfare, which they did by placing stickers on printed 5-point Likert scales. With the educators we discussed the goals of AWE, including their desired learning outcomes for a session about pet mammals and important scenarios surrounding pet mammals children might need to be educated about. We also discussed currently used tools and approaches.

Both sets of participants were then presented with three personas (see below). Participants were asked to think about why each persona might need to learn about animal welfare and what activities might help them do that. Their answers were noted by the researcher leading the small group.

The personas for this workshop were co-created with an experienced child-animal interaction researcher and a director from the Scottish SPCA who had previous experience of research collaboration. We started with a persona template that included name, age, gender, pet ownership, and optional details about interactions with pets. During our discussion, we created several different ideas and then narrowed these down to three personas, aiming to capture different relationships and experiences with common pets, from positive to negative to limited/neutral. The resulting personas included pet owners and non-pet owners. The personas also included interactions with the three most common pets in the UK (dogs, cats, and rabbits). The personas' ages matched the

age of the workshop participants and the planned intervention target group (8–12-years-old), and there was one male, one female, and one gender-neutral persona. We made the caring, affectionate cat-owner male so as not to reinforce stereotypical gender roles around caregiving, such as have been seen in Lego® sets [75], and as a gentle challenge to some boys' views that affectionate relationships with pets are 'feminine' or 'childish' [76].

The personas were as follows:

- **Alex** is 10 years old. He loves animals. He has a cat at home that he likes to play with and cuddle.
- **Bonnie** is 11 years old. She has a pet rabbit. She is scared of dogs after being bitten by one a few years ago.
- **Charlie** is 9 years old. They don't have any pets at home.

The second aspect discussed was the participants' perspective on using robotics in AWE. For the educators this included discussion of the pros and cons of the current robotics toolkit as well as envisioned benefits and challenges going forwards.

The final aspect discussed was the use of interactive narratives to structure an educational intervention. This discussion was started by giving more information on interactive narratives and an example of a choose-your-own-adventure novel. Educators were asked for their impressions of its use in AWE. The children were asked some questions about their experience with and impressions of interactive narratives.

3.1.3.3 Demonstrations Participants were shown MiRo² and Qoobo³ (Fig. 1). After a description of the sensors, actuators, and capabilities, participants were invited to interact with the zoomorphic robot and ask questions. They then returned to their small groups to give feedback on the zoomorphic robots, including likes, dislikes, what made them animal-like or not, and potential for use in AWE.

MiRo is mammal-like, biomimetic robot that is the size of a small dog. It has two HD cameras and sensors including touch sensors on the head and back, sonar, light, and cliff sensors, and four microphones. It has two differential drive wheels, a neck with three degrees-of-freedom, and cosmetic features that mean it can wag its tail, rotate its ears, and open and close its eyes. Behaviours are generated through selecting one of seven basic actions according to audio, visual, and tactile information and an internal model of affect [77]. MiRo was running a modified version of its 'demo controller' that amplified displays of emotion through the ears, eyes, and tail. This ensured the full range of motion of the



Fig. 1 Zoomorphic robots demonstrated to participants. (a) MiRo. (b) Qoobo

² <http://labs.consequentialrobotics.com/miro-e/docs/index.php?page=Introduction>.

³ <https://qoobo.info/index-en/>.

cosmetic features was demonstrated, and the controller had previously been used in research into children's perceptions of the mental attributes of MiRo [78].

Qoobo is a small, furry robot, approximately 20 cm across, with a short tail that moves back and forth. It has touch sensors in the body and two microphones. A vibration motor inside the body mimics a heartbeat. Qoobo was switched on, so the speed, amplitude, and pattern of the tail movements changed in response to sound and touch.

MiRo and Qoobo were chosen because they represented good coverage of the design space for zoomorphic robots, without incorporating humanoid features, like many other zoomorphic robots (e.g., Tega [79], Kiwi [80]). Löffler et al. [81] used participant ratings to cluster features of zoomorphic robots into key dimensions. These resolved into surface, facial, and animal-specific properties. MiRo and Qoobo represent different surface properties, the presence/absence of facial features, and a mix of animal-specific features. Ideally, a robot designed to appear as a specific animal, like Aibo, would have rounded out the set, but this could not be obtained.

3.1.3.4 Design Following the demonstrations and feedback, the educators went back into their small groups to start the design session. This began with sketching and annotating individual designs. They were then asked for some ideas for storylines or narrative framing to use.

The children's design session was formed of three main activities: brainstorming about the attributes and behaviour of pets; designing a robot pet; and completing a branching storyboard.

The first set of brainstorming prompts drew on children's senses, prompting them to think about how a pet looks, feels, and sounds. The second set of prompts were about how pets behave. No reference was made to specific pet species (e.g., cats or dogs) nor was reference made to children's own pets so that children were free to use real and imagined experiences with a variety of pets. The brainstorming prompts served to refocus children's minds onto pet animals. This, in combination with the demonstrations, was designed to ground the children's designs in terms of pets and robots, in an attempt to avoid totally fantastical creations or ones that had no elements of pets—we expected some unfeasible designs, but wanted to avoid unicorns and dragons.

The storyboard activity aimed to elucidate different interactions children envisioned with the robotic pet. A similar tool that uses narratives is the thematic apperception test. The test prompts a participant to create narratives about ambiguous images on the premise that the narratives can reveal a participant's underlying motives, concerns, and ways they look at the world [82]. Thematic apperception

tests have been used in many areas of psychological research and therapeutic practice, including interventions in cases of confirmed or suspected animal abuse [83]. The 'Animals-At-Risk' thematic apperception test uses images "surrounding common situations that might create tension in the human-animal relationship" [83, p.] 92 and is used by practitioners assessing and treating children who have abused animals or witnessed animal abuse to understand children's experiences around pets within the family setting.

In this new tool, we combined storyboards with the ambiguous, open prompt aspect of thematic apperception tests, focused on animal emotions. This provided a scaffold for the children to develop their storyboards around—prior research has found that an intermediate degree of scaffolding facilitates more idea elicitation than completely unstructured storyboards [84]. However, we did not include any images of scenarios so that children could include the robot they had designed in the previous exercise. To start, children were prompted to choose one of four emotions their robot pet could be feeling: happy, sad, angry, or scared. The panels of the storyboard were labelled with questions that prompted the child to fill in the events surrounding the emotion. Questions have been used to provide structure and prompts for participants [51, 53, 72, 85], but have previously been kept separate from the storyboard template.

Another technique newly applied to this storyboard template is branching. This enabled us to probe different potential scenarios surrounding the robot emotion. The branching occurred at the point of human action, which also reflects the use of the 'Animals-At-Risk' thematic apperception test; therapists working with children who have abused animals can help teach self-management by prompting the child to think about how their and others' reactions to the situation could be different and what the potential outcome would then be [83, p.] 67]. More branches could be added to probe different events that could have precipitated the emotion, for example, but we decided that this could become too complicated and potentially confusing. The branching storyboard template given to children is shown in Fig. 2.

3.1.3.5 Feedback The final portion of the educators' workshop involved the two small groups presenting their combined ideas to each other. The workshop then united as a full group to discuss some final points, including suggestions for how the robot could be used with groups of children, how the robot could be made customizable, and thoughts on representing a specific mammal versus a generic mammal with the robot. There was also time for participants to raise any other points they wanted to discuss.

The children's feedback session involved each small group sharing one of their ideas with the rest of the group.

MY STORY

(Please choose one)

The robot pet feels

happy sad
angry scared

What happened to make the robot pet feel this way?

How does the robot pet act?

What might a person do?

What happens next?

What else might a person do?

What happens next?

The storyboard template consists of several interconnected boxes and lines for writing. At the top, it asks the user to choose a feeling for the robot pet from a list: happy, sad, angry, and scared. Below this, there are two boxes: 'What happened to make the robot pet feel this way?' and 'How does the robot pet act?'. Arrows connect these boxes to a central vertical line that branches into two paths. Each path leads to a box asking 'What might a person do?' and 'What happens next?'. Below each of these boxes are several horizontal lines for writing. The second path also includes a box asking 'What else might a person do?' and another 'What happens next?' box, also with writing lines below.

Fig. 2 Storyboard template given to children

As a final activity, participants voted on their favorite robot of MiRo and Qoobo. The lead researcher then wrapped up the workshop, thanking the participants and allowing time for questions.

3.2 Data Analysis

The researchers' notes and the materials produced in the workshops were analysed using the constant comparative method of grounded theory [86], where codes and categories are continually compared and redefined. This method works particularly well for comparing and contrasting data across and within two groups. Content analysis was also used for the drawings. We used the same rule of thumb as Sanoubari et al. [51] where something was considered a theme if it was seen in data from at least 20% of participants (that is, 5 or more children or 2 or more educators) or included in the researchers' notes for more than one small group. The themes were validated by a researcher separate from the project who coded 20% of the data. Any major differences were discussed and resolved.

We decided to create two different affinity diagrams based on the two main design tasks, one for robot design and one for narrative design. We looked at the materials generated by the participants during the design activities and captured key information about the designs on sticky notes, using different colours to track which characteristics came from children and which came from educators. After grouping the sticky notes based on similarities, we “walked the wall”, discussing and refining the groupings into potential themes. We reviewed and discussed the themes and sub-themes before generating the two thematic maps.

4 Results

This section covers the themes identified from the workshop data, split into perspectives on AWE and robotics, demonstrations, attributes of pets, pet robot designs, and narrative designs. Participants are identified by E for educator or C for child and a number.

4.1 Discussion of AWE, Robotics, and Interactive Narratives

4.1.1 AWE

Table 2 shows six themes identified from the discussion with educators about the desired learning outcomes, along with some example quotes. These six learning objectives targeted by the educators were: awareness of animal needs and proper care; awareness of animal emotions; understanding of animal behaviour; awareness of appropriate handling; respect for animal boundaries; and awareness of the responsibilities of pet ownership. Educators felt that addressing these areas would lead to increased compassion and empathy for animals. This was linked as a consequence of understanding animal sentience and emotions, rather than directly targeted (“it all goes together”). Additionally, children’s responses to the personas touched on many of the same themes—see the final column of Table 2. The children also highly appreciated the importance of AWE, with 4 children rating it as important (the second strongest option) and 20 rating it as very important (the strongest option) to teach children about animal welfare. Children’s self-rated knowledge of animal welfare varied (poor: $N=2$, fair: $N=2$, good: $N=7$, very good: $N=6$, excellent: $N=7$). Self-rated animal

welfare knowledge largely correlated with pet ownership; all of the children who rated their knowledge as poor or fair did not own pets, but other non-pet-owners rated their knowledge as good, very good, or excellent, similar to the pet-owners.

Educators use a range of tools and activities in their programs including quizzes, memory games, scenario cards, and an emotion wheel. They have also used a modular robotic kit (Sect. 2.1). Children suggested similar activities, like games and quizzes, as well as a writing exercise for Bonnie (one of the provided personas) to engage with the feelings she experienced when bitten by a dog. Another of their ideas was learning through experience, through interactions with a pet in a safe environment or with a substitute like a zoomorphic robot or stuffed toy. Educators also explained that there are different education programs for different needs. Most children participate in the mainstream program, Animal WISE, but children who have shown concerning behaviour towards animals may be recommended for another one-to-one program.

The educators stressed the importance of educating all children about animal welfare, not just those with pets, as children without pets are still likely to interact with animals, whether in the wild or at a friend’s house. The children also recognised this, saying that Charlie (the persona without pets) “might have friends who have animals”.

Table 2 Learning objectives in AWE

#	Description	Quotes from Educators	Quotes from Children
1	Awareness of animal needs and proper care	“needs of an animal”, “five freedoms” ^a , “shouldn’t be neglecting pets’ needs”	“make sure he knows how to care for his cat”, “nice place to sleep in”, “how to keep a cat active”
2	Awareness of animal emotions	“teaching about animal emotions”, “happiness, sadness, fear, pain, anger”	“he has a cat and wants to learn about its emotions”, “her rabbit might have different emotions”
3	Understanding of animal behaviour	“understanding why she was bitten”, “didn’t recognise the signs”	“she wants to find out why the dog bit her”, “his cat might bite if stressed”
4	Awareness of appropriate handling	“gentle handling, not grabbing”	“play in a gentle way”, “how to interact with a dog in a safe way”
5	Respect for animal boundaries	“not disturbing them when they’re eating or sleeping”, “have its own space”	“maybe if cat doesn’t want to cuddle he should know”
6	Awareness of responsibilities of pet ownership	“responsibilities of having a pet”, “broader responsibility”, “need to microchip”	“if sick, take to vet”, “how to do chores so that they get a pet”

^aThe five freedoms for animals are: freedom from hunger or thirst; freedom from discomfort; freedom from pain, injury, or disease; freedom to express normal behaviour; and freedom from fear and distress [87]

4.1.2 Robotics

Educators were positive about the interactivity of zoomorphic robots, especially the ability to respond to sensory input, and the adaptability of zoomorphic robots to different situations and activities. They also anticipated high engagement from children due to the novelty of zoomorphic robots. However, they were concerned that the excitement of new technology could be a distraction from the main purpose of the activity, i.e., learning about pets. They also had mixed feelings about how realistic a zoomorphic robot could and needed to be for children to relate it to a pet and apply skills learned using the zoomorphic robot to real life.

A major concern for the educators was technical issues, centered around setup, connecting robots and controllers, and battery life—all of which they have experienced with the robotic toolkit. Issues like these require educators to adapt programs on the fly, wasting the limited time they have with classes and causing them stress.

Educators have experienced rough handling of toys and robots, which is a reason for using zoomorphic robots over live animals in schools. However, they expressed concerns about children being rough towards the zoomorphic robot if there is no immediate negative feedback from it. These concerns related both to damage to the zoomorphic robot and

to the precedent it could set around acceptable behaviour towards pets.

Children thought zoomorphic robots could be used to teach about pet care, including how and how not to interact with pets, and pets' responses to different actions. Two groups noted zoomorphic robots would let children learn through experience in a low-stakes environment and children who had bad experiences with pets might be less scared of zoomorphic robots.

4.1.3 Interactive Narratives

The educators liked the focus interactive narratives would give to the consequences of actions. For this to be effective, they stressed that the children would need to be able to see a clear response and have the opportunity to understand the link between the action and the response. They also felt that giving children control over the narrative would engage them and make them more likely to respond. The importance of interaction design for groups was raised as key to preventing arguments among children about narrative choices.

Children expressed interest in interactive narratives and several of them had experience of interactive narratives through choose-your-own-adventure books, video games, and interactive shows on streaming platforms. Some had been involved in collaborative storytelling games which, while not exactly the same, provide a similar sense of agency. They described interactive narratives as fun, interesting, and exciting because of the control it would afford them and the unpredictability of the story. However, some children preferred the structure provided by a traditional story.

4.2 Demonstrations

4.2.1 MiRo

Both educators and children liked Miro's interactivity, particularly its visible response to touch. They also both liked the lights on the back that represent emotions through colour, which educators felt was an easy-to-understand way to communicate emotions. However, two groups of children noted the lights were not animal-like. The educators further appreciated the expressive facial features (like the moving eyelids and ears) and how these were used in reaction to the environment. The facial features played a part in children connecting MiRo to pets, as children in three groups referenced its nose, ears, and eyes to compare MiRo to rabbits and dogs. The educators disliked toy-like aspects of MiRo, particularly the noises and wheels, and neither educators nor children liked MiRo's plastic and 'robotic' appearance,

which one child described as "creepy" and an educator described as "[not] nice to touch".

4.2.2 Qoobo

Educators expressed that Qoobo had the feel of an animal due to its heartbeat, fur, and the responsiveness of its wagging tail. However, they struggled to see a use for Qoobo in AWE because it was distinctly unlike pets in certain ways due to its limited actuation and lack of facial features, meaning it cannot produce expressions. These were aspects that the children noted made Qoobo unlike pets, but they still felt Qoobo was more similar to pets than MiRo. This seemed to be due to its furry appearance, with one child saying "[you] might have to look twice to tell [Qoobo] is a robot". Children also liked the feel of the fur and described it as "fluffy" ($N = 8$). There were also multiple comments ($N = 16$), often several per group, calling Qoobo "cute".

4.2.3 Use in AWE

Both groups thought the zoomorphic robots could be used to show children how to treat animals. Educators proposed two key modifications to the zoomorphic robots for use in AWE, namely the inclusion of negative reactions and more expressive features. The negative reactions would help children understand how not to treat pets (e.g., being loud, rough handling), and the eyes, ears, tail, and noises would be used to communicate the zoomorphic robot's displeasure. Another suggestion was items for the zoomorphic robot to interface with that could provide an objective for the interaction, like collecting items that pets need. The educators also felt the zoomorphic robots' non-specific mammalian nature would make it hard for children to relate them to pets. However, children compared the zoomorphic robots to different pets, including their own, and seemed willing to view the zoomorphic robots as animals, albeit unusual ones.

4.2.4 Preferences

Children slightly preferred Qoobo to MiRo (14 votes to 10 votes). Educators were not asked explicitly for a preference, but scribes noted one for MiRo during group discussions.

4.3 Attributes of Pets

In brainstorming about pets' appearances, children listed features common to many species (e.g., eyes, ears, tails, and legs) and some specific to species ("udders" [C6], "feet like a chicken" [C15]). Most children who described pets' size wrote "small" ($N = 8$), but some ($N = 2$) used "big". Children made aesthetic judgments about pets' appearances,

mostly that they were “cute” ($N = 13$), though one child said “scary” [C20]. They also ascribed positive traits to appearances, like “happy” [C11], “friendly” [C1], and “calming” [C23].

Children referred to different textures that pets could be, including soft ($N = 14$), fluffy ($N = 13$), furry, scaly, rough ($N = 2$), smooth, silky, and leathery ($N = 1$). They also mentioned signs of vital processes, such as warmth ($N = 3$) and a heartbeat. Children also extended this prompt about tactile sensation to the quality of tactile interaction (“cuddly”, “snuggly”, “cosy”) and how a pet makes them feel (“calming” [C18], “peaceful” [C1], “makes you feel good” [C24]).

Children listed a variety of sounds made by pets, including those specific to different species (dog noises, cat noises) and the sounds associated with the movement of feet and tails. They used onomatopoeia to describe other noises. The children also highlighted the volume of sounds; four said soft or quiet, one said loud, one said both. Some children also viewed the sounds as a method of communication, conveying emotion or a meaning, like “feed me”.

To describe how pets acted, children listed different movements, emotions (from simple to complex), and energy levels. They also gave examples of needs, like food, water, and sleep, and preferences that pets might display. Children pointed out pets’ responses to the environment and the actions of others. Pets’ behaviour was sometimes related to themselves and the home (“live with me” [C23], “cuddle with me” [C16], “jump on my lap” [C3, C4]).

Children noted the variety between different species commonly owned as pets, seen through individuals mentioning mutually exclusive textures (“fluffy, scaly, leathery” [C10]) or noises from different species (“barks, miaows”, $N=4$).

However, children who seemed to focus on a single species still referred to variety within the pet, for example, that they could be happy and angry ($N = 6$). This linked to an idea of temporality—that pets did things “sometimes” ($N = 4$).

4.4 Pet Robot Designs

The thematic map in Fig. 3 shows three high-level themes from the data, described as appearance, behaviour, and features. Examples of educators’ and children’s designs are shown in Figs. 4 and 5 respectively. The full collection is available online.¹

Two children designed humanoid robots instead of pet robots, so these were excluded from analysis. Some children created multiple designs—features from all of them were collated for analysis.

4.4.1 Appearance

4.4.1.1 Surface Similarities were seen in and across the groups for the zoomorphic robot’s surface texture and colour. A design was counted as furry if it was labelled with soft, furry, or fluffy, or if the drawing style conveyed a furry texture through soft, feathery, or bumpy edges. Three educators and 12 children explicitly labelled the texture as furry, but a total of 7 educator and 15 child designs appeared furry through their drawing style.

The groups used colour in a similar way. The drawings were mostly in pencil, but when colour was used on the zoomorphic robot’s body it was often brown or orange (natural fur colours) or labelled as “same color as Qoobo” [*sic*] [C18] (light brown). Other colours tended to be used for

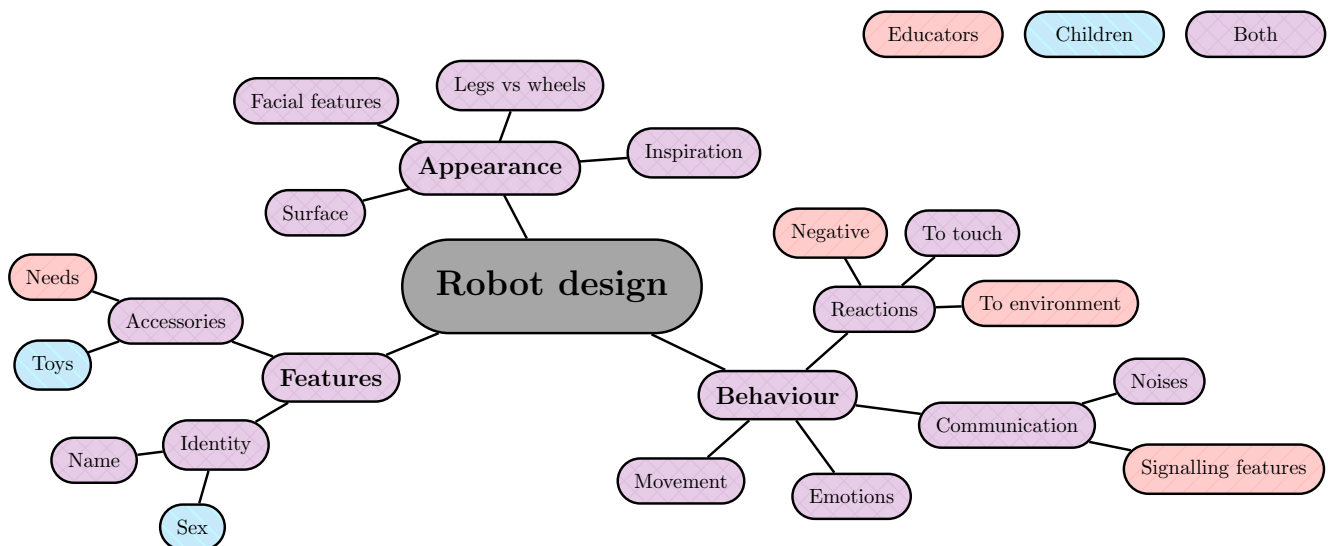


Fig. 3 Developed thematic map for robot design, showing three main themes and sub-themes, which are colour-coded by the group of participants they were observed in

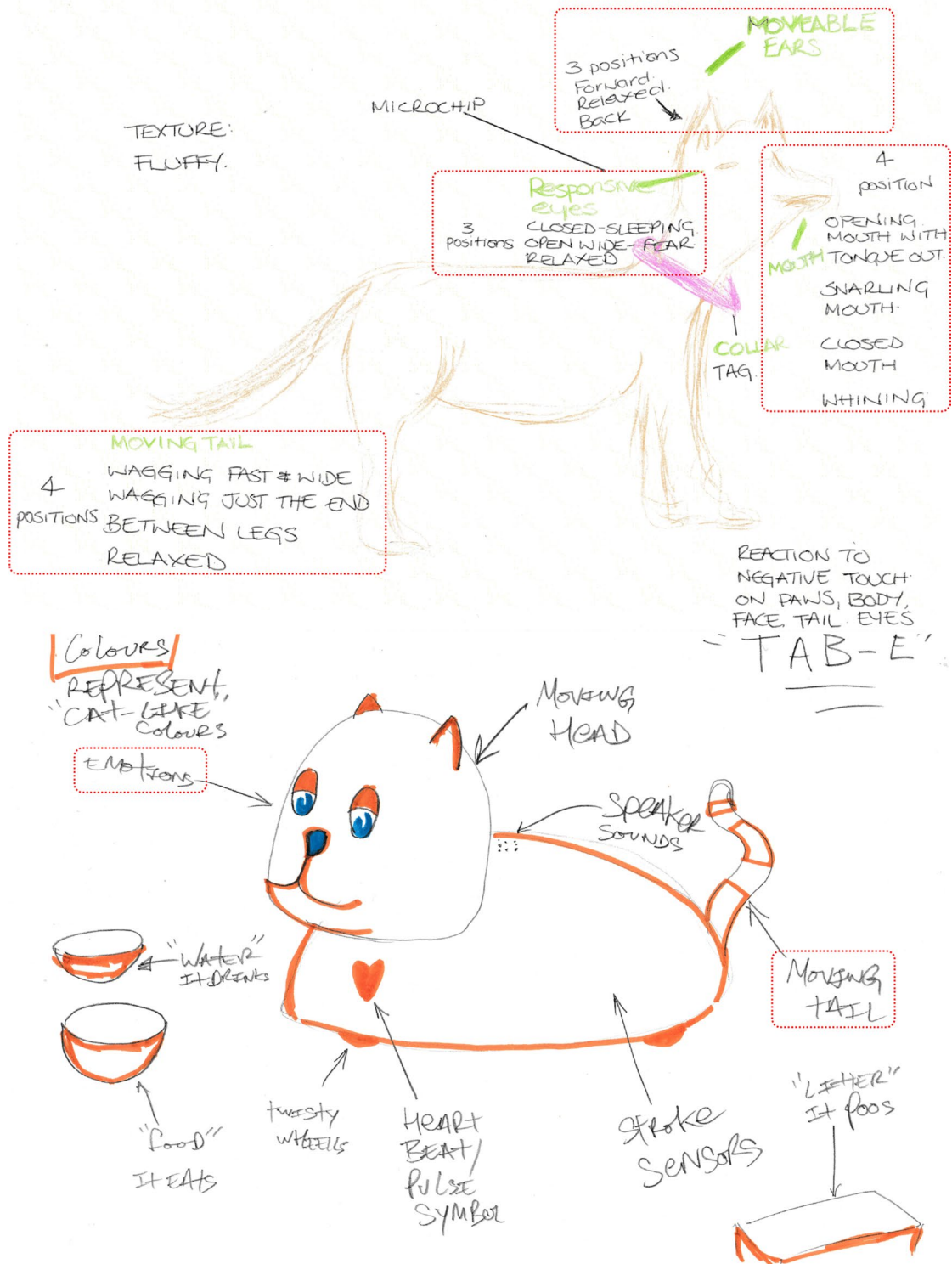


Fig. 4 Examples of educators' designs [E3, E6]. Movable signalling features are outlined in red

accessories, like collars and toys [E3, E8, C4, C19, C24], and to highlight small features, like eyes and ears [E6, C11, C15].

4.4.1.2 Legs vs Wheels It did not seem to matter whether the zoomorphic robot used legs or wheels to move around as there were designs in both groups that used legs and designs that used wheels; roughly half of each group incorporated

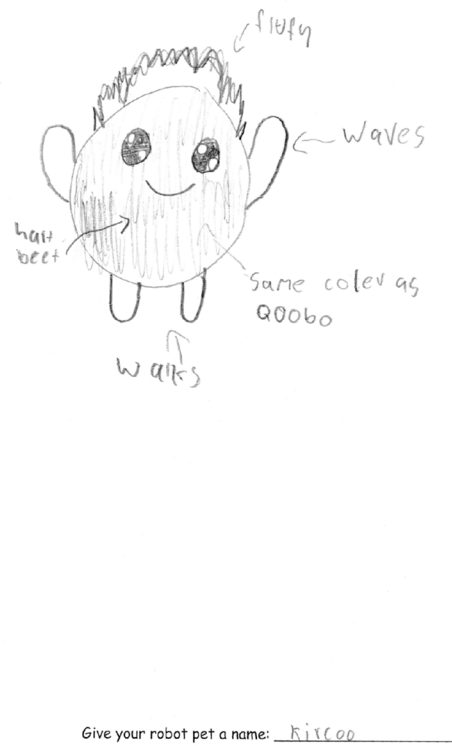
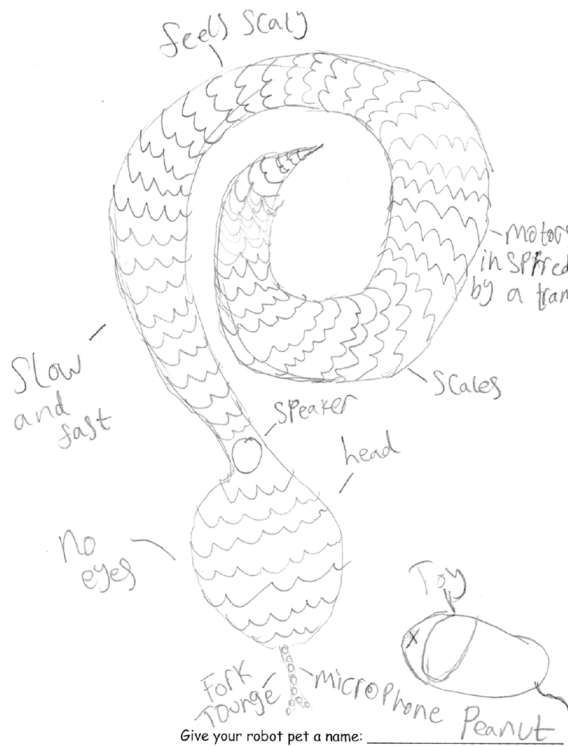


Fig. 5 Examples of children's designs [C10, C11, C12, C18]. Movable signalling features are outlined in red

wheels. However, an educator raised the concern that children seem to link wheels to racing, which makes a zoomorphic robot more toy-like, so wheels need to be unobtrusive or “hidden” [E11].

4.4.1.3 Facial Features Ten of the educators included eyes, ears, a mouth, and a nose in their design; the final design omitted only a mouth [E1]. These were also the four most common facial features included by children in their designs; eyes, ears, a mouth, and a nose were included by 82, 73, 55, and 50% of children respectively. Both groups included species-specific facial features, e.g., whiskers on cat-inspired zoomorphic robots [E1, E8, E11, C15, C19]. Five educators and six children labelled a facial feature with the associated sense, i.e., the eyes had sight/cameras and ears had hearing/microphones.

4.4.1.4 Inspiration All but one of the educators’ designs were analogous to specific pets currently targeted by AWE (5 dogs, 4 cats, 1 rabbit). One educator design was specific but with interchangeable ears for future years of the program [E1]. In contrast, the children tended to merge elements from different species and create non-specific animals. The children also drew on a wider range of species for their designs, including large mammals (cow, horse, goat), birds, and reptiles. The majority of designs ($N = 17$) did seem to be inspired by mammals, as they had tails ($N = 17$) and were furry ($N = 15$).

A couple of the children’s designs were anthropomorphic, showing features or behaviours that are more human-like than animal-like. For example, the fourth design in Fig. 5 [C18] shows a bipedal creature waving, which is not a common animal behaviour. Another anthropomorphic aspect is the smile, which was seen in a second child’s design [C23]; animals may bare their teeth or appear to smile, but this does not generally indicate happiness or pleasure [88]. No anthropomorphic features were seen in the educators’ designs.

4.4.2 Behaviour

4.4.2.1 Reactions A key component of 82% of the educators’ designs was negative reactions, which they framed as vital for teaching children what behaviour is not appropriate towards pets. Negative reactions included pulling away from interactions, either removing the body part [E4] or retreating completely [E5], and displaying warning signs, such as growling [E1, E2, E7], hissing [E1, E8, E11], or baring teeth

[E3, E4, E5, E7]. Educators wanted negative reactions even if they could be scary as, ultimately, the interaction is safe.

Tactile interactions are an important way children interact with pets. Five children included tactile interaction in their design, either through the zoomorphic robot sensing touch or ‘liking’ tactile interaction (“likes to get petted” [C24] or “like[s] cuddles” [C16]). Educators stressed the zoomorphic robot needed to distinguish gentle from rough touch, like pulling and poking, as well as sensing when children touch sensitive areas, like the paws, tail, and face, particularly around the eyes.

Educators also wanted the zoomorphic robot to be sensitive to its environment. This was broadly presented in a negative context, like the zoomorphic robot fleeing from loud noises, rough handling, and aggressive movements. While nine children included sensors that could detect these things, only C14 included corresponding reactions like “reacts if people are shouting and get’s scared” [*sic*] and “when cold he shakes and wimpers” [*sic*].

4.4.2.2 Communication Children’s designs frequently included noises or a speaker to produce them ($N = 12$). The educators wanted the noises to fit the species being taught about—barking, whining, and growling for dogs and hissing, miaowing, and purring for cats—as opposed to MiRo’s ‘mammalian voice’. Similarly, when children gave detail on the noise, it matched the apparent inspiration, e.g., barking for a dog. The educators wanted the noises to convey the pet’s emotions and ask for attention when appropriate. No participant designs showed the zoomorphic robot communicating with speech.

The educators highlighted the way a pet’s facial features and tail can be used to communicate, which we refer to as signalling features. A large proportion labelled these features with specific positions or movements they wanted, examples of which can be seen in Fig. 4. For example, six educators labelled the eyes as able to blink or take different positions, from closed to relaxed, to wide open. Similar specifications were attached to the other features (ears: $N=9$, mouth: $N=7$, nose: $N=3$, tail: $N=10$). When we remarked on this level of detail, educators explained that people must notice and understand the movement and positions of these features in order to have positive interactions with pets, since they communicate the internal state of a pet. Many children included the same features but were much less likely to provide further specification (Fig. 6). The feature they most commonly labelled as movable was the tail (by 32%) where the description given was mostly “wags”—compare this to E3 who gave four movements for the tail (Fig. 4).

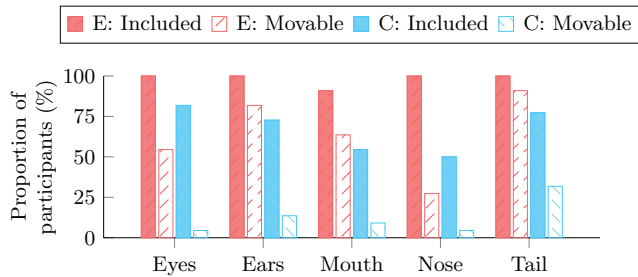


Fig. 6 Proportion of educators (E) and children (C) who included signalling features. Examples of movable signalling features are shown in Figs 4 and 5

4.4.2.3 Emotions The educators' designs suggested the zoomorphic robot would have five main emotions: happiness, sadness, anger, fear, and pain (Table 2). These emotions would be influenced by the environment and interactions, and would be displayed through noises, body language, and/or coloured lights in the eyes or back. Additionally, five of the children's designs implied the zoomorphic robot would have emotions or "mood". Some labels specified reactions in response to emotions ("makes *mmmmmm* sound when happy" [C9], "ears wiggle when very happy" [C10], "when he's scared his ears go back" [C14]). Two children included coloured lights to display mood [C2, C4].

4.4.2.4 Movement Both educators and children described the zoomorphic robot's movement on a range of scales, from the large, like moving around in space, through the medium, like moving the head and wagging the tail, to the small, like twitching the nose and blinking the eyelids. A number of educators and children also included trembling [E1, E7, C14] and a heartbeat [E6, E11, C10, C17, C18, C19].

4.4.3 Features

4.4.3.1 Accessories Three of the educators' designs included peripheral items for the zoomorphic robot. Examples of these were a bed, a litter tray, food and water, and a tablet to display the zoomorphic robot's internal state. The educators also explained that peripheral items could be used to split children into smaller groups doing different activities, rather than one large group. Three of the children included peripheral items in their design, but while the educators focused on pets' needs, all the children's items were

toys. An accessory common to both groups was a collar (seen in three educator and four child designs).

4.4.3.2 Identity Children were prompted to name their zoomorphic robot and 19 did so. There were names inspired by Qoobo and MiRo (e.g., Meqzo, Qute, Birbo) and pet-like ones (e.g., Bailey, Coco, Mickey). Designs with names in the former category were often more robot-like, with features like propellers and solar panels. Designs in the latter group tended to closely resemble specific pets, like cats or dogs. Four children used the name to personalise the zoomorphic robot by the zoomorphic robot coming with a collar or birth certificate. Naming was also relevant for behaviour, as two children wanted the zoomorphic robot to come when its name was called [C1, C14]. Only one educator named their design, "TAB-E" [E6], but both groups discussed the zoomorphic robot responding to its name.

59% of the children referred to their zoomorphic robot with male pronouns, 32% with gender-neutral pronouns (*it/they*/a mix of the two), and 9% did not use pronouns (pronoun usage was cross-referenced with their storyboard if not discernible from their design alone). No children used female pronouns for their zoomorphic robots, but two children said their zoomorphic robot could come as a female version [C10, C14]. 45% of the educators used *it* to refer to their zoomorphic robot and the rest did not use pronouns in their drawings.

4.5 Narrative Designs

This section presents the themes coded to the educators' small group discussions about the narrative for the robot and the children's storyboards. Figure 7 shows three themes, identified as topics, plot elements, and actions.

As with the robot designs, only the narratives from the 22 children who designed a robot for AWE were analysed. Children could choose from four emotions that the robot was experiencing at the start of the story: happy, sad, angry, or scared. 10 children chose happy, 1 chose sad, 2 chose angry, and 9 chose scared. 17 storyboards were complete, 2 were almost complete (missing 1 panel), and 3 were half complete (missing 2–3 panels). 18 children used writing and drawing to complete the storyboards, 3 used only writing, and 1 used only drawing.

4.5.1 Topics

This concept related to what the key topics and takeaways of the narrative would be.

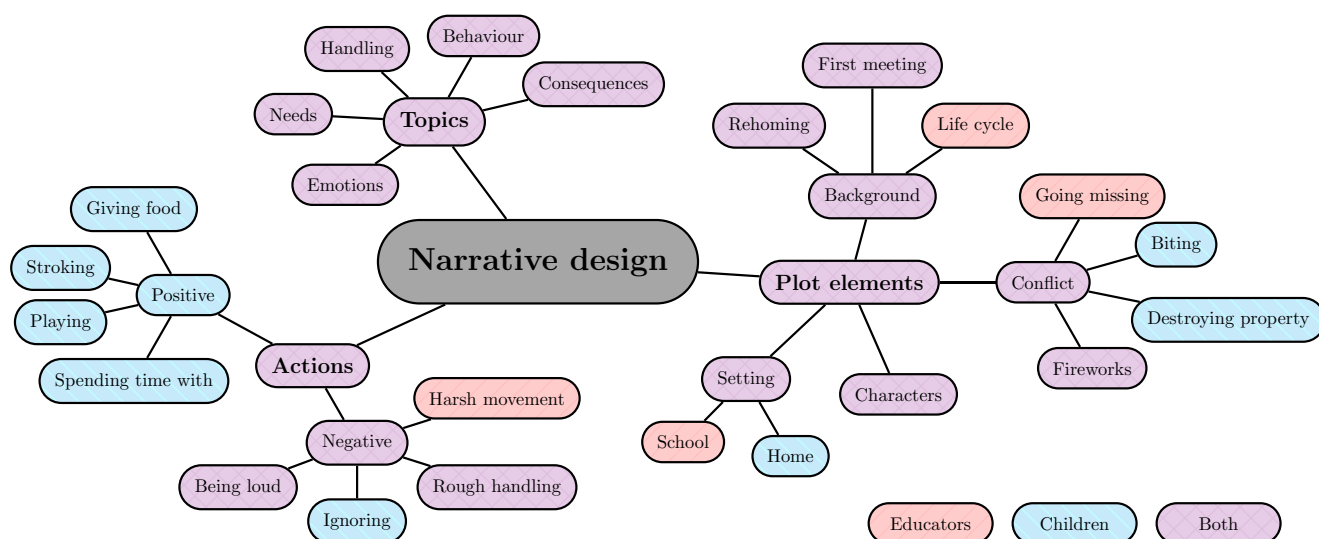


Fig. 7 Developed thematic map for narrative design, showing three main themes and sub-themes, which are colour-coded by the group of participants they were observed in

4.5.1.1 Emotions Educators talked about the way the robot could convey emotions through appropriate reactions to events in a story. The goal would be for the children to understand what emotion the robot was experiencing and why that emotion had occurred. All the children’s storyboards included an emotion due to the prompt, but half of them ($N = 11$) had an additional, different emotion as the outcome of the story as a result of the events in the story.

4.5.1.2 Needs The educators looked for ways the narrative could be used to convey animals’ needs, as well as emotions. They also highlighted providing needs as an easy way children could make choices in the narrative, such as the type of food to provide or where to take it if it were ill. One group of educators suggested a story around a journey to collect what an animal needs, using devices to track progress, like a heart that fills up. Five children’s stories were coded with the theme of needs, four of which focused on providing food, but two of which extended to environmental and behavioural needs, such as the need to play or spend time outside [C12, C18]. The food in the children’s stories was a mixture of regular pet food and explicitly “robotic” food, like batteries.

4.5.1.3 Handling Following on from the robot designs, the educators highlighted the importance of teaching children handling skills. They suggested the narrative could include instances of handling, acted out by the children, and the robot would react in different ways, with positive and negative reactions as appropriate. Handling was also a common theme in the children’s storyboards; nine of them pictured

or described the person handling the robot animal in some way, mostly petting or stroking it but sometimes carrying it ($N = 3$). Additionally, three narratives used the branching to show the differences between rough and gentle handling and their effect on the animal [C1, C2, C16]. The stories showed that grabbing an animal or petting it in the wrong place (e.g., the tail) would distress the animal and might make it run away, contrasted with gentle stroking that would make the animal happy and facilitate bonding.

4.5.1.4 Behaviour Educators wanted the narrative to have displays of animal behaviour in different situations. They would then use these to teach children how to interpret these behaviours and react appropriately. Several storyboards showed that some children already have a good grasp of animal behaviour. Examples of this included the potential causes of emotional states, like loud noises causing fear, but also how the pet robot would display the emotion. For example, several children who had designed a robot pet inspired by dogs gave correct examples of dog behaviour for fear, like cowering, shaking, and whimpering. The educators further stressed that it would be key that the behaviour of the robot matched what an animal would do at each point in the story and be appropriate to the inspiration (i.e., rabbit behaviours for a rabbit-like robot).

4.5.1.5 Consequences Educators wanted the narrative to show children the consequences of their actions. One such example involved the robot being initially shy but through “the class making the right choices” the personality would change to more confident and playful. They also wanted

negative outcomes and reactions to poor choices, such as giving a dog chocolate or not getting a pet vaccinated. The children's storyboards also showed a connection from people's actions to the outcome of the story. Children frequently ($N = 10$) presented polarised storylines, where there were distinct positive and negative options and the outcome of the story varied accordingly, even though the prompts were neutral ("What might a person do?" and "What else might a person do?"). On two occasions, these storylines were explicitly labelled 'good' and 'bad' [C11, C15] (see Fig. 8).

4.5.2 Plot Elements

This concept related to the aspects that make up the sequence of events in a story.

4.5.2.1 Background The educators came up with several different ideas for the narrative the robot would form a part of. They wanted realistic, animal-centered scenarios that could conceivably happen to a pet, such as encountering new people or going missing on a night with fireworks. They considered scenarios that linked to their organisation, such as an animal's journey from rescue to rehoming. The children's storyboards covered similar scenarios to the educators, with three narratives revolving around the rehoming or abandonment of a pet.

A couple of the educators' ideas involved seeing changes over time. One such idea revolved around short-term changes; the robot's personality would change over the course of a session, from shy and easily startled to more adventurous and playful if the class treat it correctly. Another idea focused on the long-term changes experienced in an animal's lifetime, for example the differences in behaviour and needs between a puppy, an adult, and an elderly dog.

4.5.2.2 Conflict There were some suggestions from educators for narratives with negative events, like a dog going missing or getting ill, but some cautioned against being too negative as they considered this could dampen enthusiasm and lose some children. However, children themselves did not avoid negative scenarios, and some stories of theirs revolved around people's potential reactions to the robotic animal biting a person or destroying property. As with educators, the children included the distressing effect of loud noises, like fireworks or shouting, as events that caused the robot to become scared.

4.5.2.3 Characters The main human character in the children's storyboards was generally, but not always, the owner.

Children also included other animals in the interactions. Some of the educators' ideas positioned the children as the pet owner, but in other ideas the children were meeting a robot owned by someone else.

4.5.2.4 Setting The children's storyboards suggested they mostly envisioned interactions with a robot pet within the home (eight had drawings showing interiors and furniture). In contrast, educators described interactions within a classroom environment, explained by the animal visiting the school with the educator.

4.5.3 Actions

This concept related to the actions a person takes during interaction with the robot, both positive and negative.

4.5.3.1 Positive Children particularly focused on the positive ways that people could interact with the robot animal. These included giving it food, stroking it or engaging in gentle touch, playing with it, and simply spending time with it. This last interaction was seen in four storyboards where the robot sat next to the child on a sofa or bed (e.g., "let him sit on the couch with them" led to "he would be happy" [C3]). In five storyboards, children presented only positive options, like patting the robot or taking it outside [C18], or playing with it or letting it sleep [C9].

4.5.3.2 Negative In contrast to the children, the educators focused mainly on negative interactions and teaching children what not to do. Negative actions included being loud, moving suddenly or crowding the robot, and rough handling. Children also included negative actions; nine storyboards featured some form of negative action, including being loud, ignoring or neglecting the robot, and handling the robot roughly.

5 Discussion

As in-school AWE presents a new use case for zoomorphic robots, it is important to understand the perspective of animal welfare educators when approaching their design, and this work marks the first instance of involving animal welfare educators in the design of a zoomorphic robot. The work also benefits from seeking the input of children for the design of a zoomorphic robot, with the paralleled structure

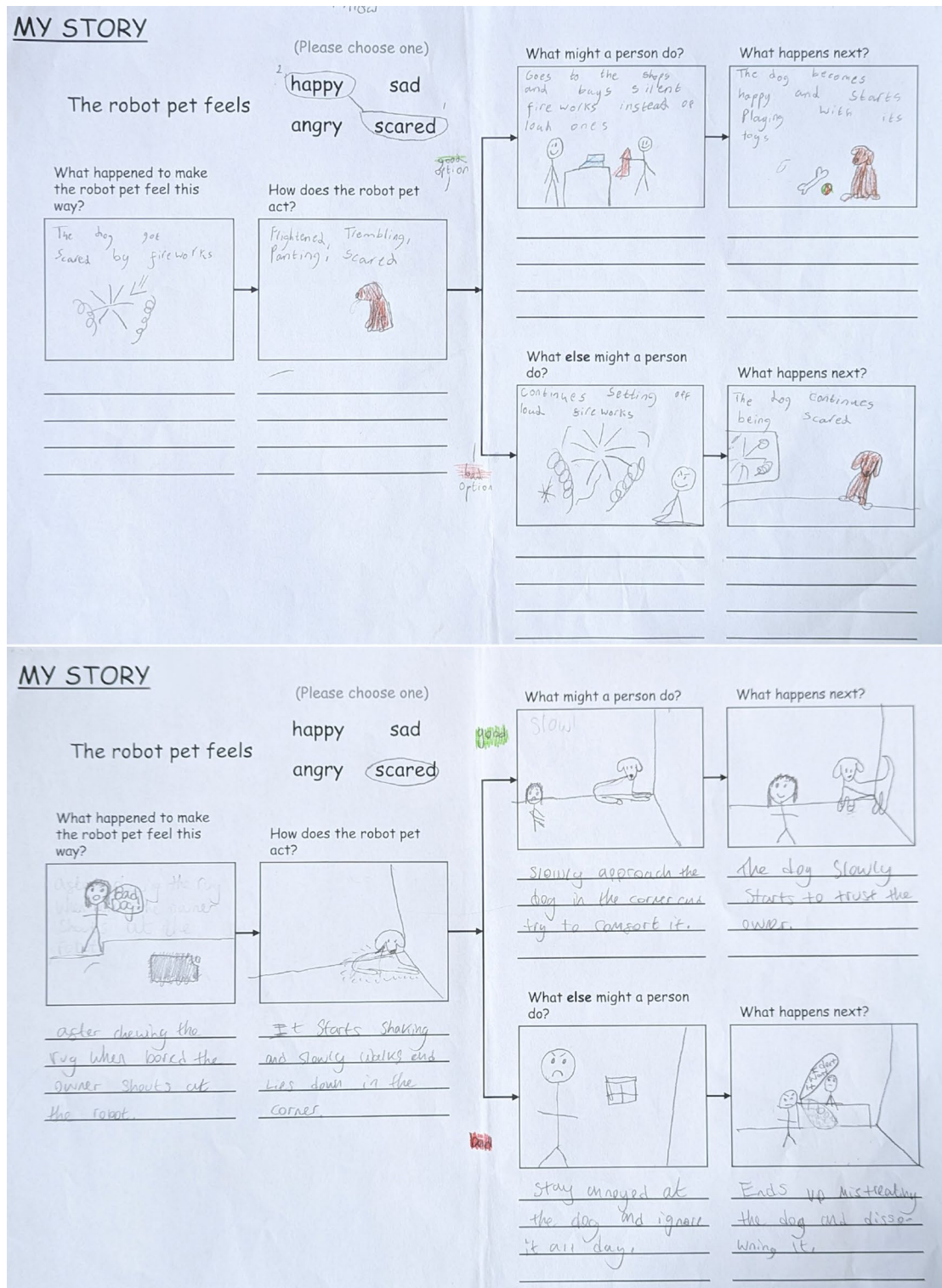


Fig. 8 Examples of completed storyboards [C11, C15]

of the workshops and activities allowing us to identify similarities and differences between the two groups.

5.1 Design Considerations

While the focus of this research was animal welfare education, zoomorphic robots have been investigated for a range of applications and are commonly used in an attempt to achieve benefits similar to those associated with real pets. Thus, research has investigated their use as a calming companion for those with depression [29], anxiety [89], and eating disorders [90], and for elderly people living in care homes [91]. With children, zoomorphic robots are often toys, but are also similarly used as a non-judgemental source of support to help children cope with pain and anxiety, usually in hospital and therapeutic settings [92–96].

Our findings reflect some aspects from Collins et al. [29] about a zoomorphic robot for adults with depression, like a preference for a familiar mammalian appearance, a soft, natural-coloured covering, natural noises, and touch sensors for calming tactile interactions. Likewise, the suggestions from Barber et al. [92] for changes to a zoomorphic robot to improve it for use in therapy with children include similar aspects, like fluffy fur and more life-like behaviour. This suggests a zoomorphic robot developed according to our findings could be suitable for therapeutic purposes.

Additionally, the perspective presented by the animal welfare educators also shifts the focus from entertainment to education, emphasising aspects not commonly found in commercially available zoomorphic robots, like signalling features and aversive reactions. However, an educational focus may be desirable for zoomorphic robots targeted at children. Materials surrounding zoomorphic robots for children often position the child as the robot's carer (Furbies designate the child as a "Mommy" or "Daddy" [97]), and some feel that owning might help teach children responsibility and care for future pet ownership [98]. Therefore, it could be advantageous to incorporate the key features identified in this work into these robots that position themselves as educational.

5.1.1 Design Principles and Guidelines

With these two additional applications in mind, we summarise our findings into the following four design principles for a robotic system aimed at promoting kind, caring behaviour to pets. We also include design guidelines for the implementation of each principle. We advise the resulting system should:

1. Discourage unwanted behaviour, encourage wanted behaviour
 - (a) Respond with fearful and even aggressive reactions when children engage in behaviours that we want to discourage during interactions with real animals
 - (b) Cover the robot with natural-coloured fur to promote the link to real pets and encourage gentle tactile interaction
2. Use displays of emotions to inform and guide child behaviour
 - (a) Develop a selection of positive and negative emotions to be used in response to children's behaviour to communicate if the behaviour results in a positive or negative experience for animals
 - (b) Display emotions via animal-like modalities, using movements of the facial features, ears, and tail, rather than relying on robot-like modalities
3. Navigate different user priorities
 - (a) Use pet care and play accessories to draw on children's existing role in relation to pets (play) and to guide them to the desired role (responsible care)
4. Highlight consequences of actions
 - (a) Create a narrative around the robot to convey the impact of choices and actions
 - (b) Include in the narrative a balance of positive and negative events that reflect common or important child-animal interaction scenarios

5.1.2 Additional Questions to Address

The workshops identified some clear areas of consensus to prioritise for the design of a zoomorphic robot for AWE, but there were also some differences to navigate. Here we outline key questions in this regard and provide some suggestions to resolve conflicts.

5.1.2.1 Should the Robot Be a Specific Species? The physical features included by most participants (children and educators) in their zoomorphic robot were eyes, ears, a mouth, a nose, and a tail (Fig. 6). These align with features of prototypical mammals selected by children [99, 100]. While several children mixed aspects of mammals, the educators' designs were usually a specific mammal. This may be because educators recognise that needs and behaviours are species-specific. For example, tail wagging may signify excitement in dogs but irritation in cats, though this is also context-specific [101]. Therefore, while a non-specific zoomorphic robot could be used to simulate a range of pets, its

behaviours would need to be common to multiple species or modified for the specific species taught about.

5.1.2.2 Should the Robot Be Cute? A recurring theme in the children’s workshop was cuteness. This came up in the feedback on the zoomorphic robots (Sect. 4.2) and in the brainstorming about pets (Sect. 4.3). However, the educators did not use the word cute. Animals, particularly domestic mammals, are widely viewed as cute [102, 103] and have been used as cute stimuli in studies [104, 105], but it is interesting to see cuteness applied to the zoomorphic robots, albeit to different extents. In the brainstorming about pets, “cute” tended to coincide with physical attributes like fluffy, furry, soft, and small, which may explain why “cute” was applied to Qoobo more than MiRo ($N=16$ vs $N=2$). Research on cuteness shows it captures and secures attention [106, 107], and influences preferences [108]. Therefore, it may also have played a part in 14 of the children preferring Qoobo to MiRo. Given the engaging appeal of cuteness, as well as the idea that harm to cute beings is morally proscribed [109], it seems ideal for a zoomorphic robot for AWE to be cute. However, many features associated with cuteness—big eyes, round flat faces, etc. [110]—have negative health consequences in pets [111, 112]. This raises a key question over if cuteness should be a design goal for zoomorphic robots, particularly when the focus is animal welfare. Rejection of cuteness would go against the trend in many products [113, 114], and a further question arises over a suitable design alternative. This finding merits in-depth interdisciplinary discussion with designers, psychologists, and animal welfare experts.

5.1.2.3 What Should the Framing Be for the Robot? The difference in narratives between children and educators raises challenges for the framing. Children often have strong personal relationships with their pets [115, p.] 27–28] and these relationships exist in the context of their home, which we saw in the setting of their storyboards (Sect. 4.5.2). However, in this use case, the robot will be used in a school, so we need to consider how to navigate this incongruity. This could be done by developing a robot backstory. Backstories can engender empathy towards a robot [116] and help children form an initial connection to it [117]. However, Michaelis et al. [118] find that children can be disbelieving about certain backstory comments made by a robot, and suggest backstories should be designed to have clear ways of making sense of them and fit with the robot’s capabilities. For our purpose, the robot could be positioned as a new arrival from the rescue center that needs to get used to people before being rehomed or as the educator’s own pet

that they take into schools, much like Martha and Gibson, existing mascots for the Scottish SPCA [119].

5.1.2.4 How to Convey Emotions? As shown in Fig. 6, the educators focused on how the zoomorphic robot could include and use signalling features, due to their importance in communicating internal state. Previous work suggests recognizable emotions are possible with zoomorphic robots. For example, videos of MiRo producing 11 affective expressions (including happy, sad, scared, and angry) were recognised significantly above the chance level [120]. Other work has used characteristics like ear stiffness, breathing rate and depth, and purring to successfully convey the arousal of a zoomorphic robot [121]. However, in the study by Ghafurian et al. [120], negative expressions were more likely to be miscategorised, with fearful and angry only successfully recognised by 32 and 28% of participants respectively. Similarly, participants in the study by Yohanan and MacLean [121] failed to identify low valence. This could be due to the expression design and actuation limitations, but may also reflect a wider difficulty identifying negative affect in pets [122–124].

5.2 Lessons Learned

5.2.1 Reflections on Design Process

Using a similar workshop structure and activities for educators and children worked well. In particular, it allowed us to appreciate children’s contributions to the design. While children do not have expert knowledge about features needed for an AWE intervention, they are the experts on their own experience with pets, and the data gave insights into their perceptions of pets (e.g., the importance of personal relationship, variety, and cuteness).

The workshop activities helped the children produce grounded, realistic designs that followed the brief. The designs did not simply reproduce the demonstrations, but did incorporate features from them, like different sensors, suggesting the demonstrations influenced them to include technical features in their designs. The prompts about pet attributes and behaviour functioned similarly, as several children used an attribute they had brainstormed directly in their design, as in Sanoubari et al. [51].

The draw-and-write approach allowed the children to customise the balance of drawing and writing, from one drawing with no writing to one with 24 labels. There were some labels that were difficult to decipher, which is to be expected when working with children this age, so it would be beneficial to look into methods like draw, write, and tell

[69] to give the children a chance to clarify and expand on aspects of their designs. Unfortunately, this method is very time intensive, which is why it was not used here.

The branching storyboards were a highly effective tool for gathering rich data from the children. Firstly, the level of scaffolding seemed to strike the happy medium described by Moraveji et al. [84], where there was enough guidance to avoid children feeling overwhelmed by options, but enough freedom to share a range of ideas. Secondly, the storyboards provided insights into the extent of children's animal welfare knowledge, potential actions they could take, and potential consequences to these actions. Several storyboards gave correct interpretations for the behaviour of common pets and the underlying reason for this behaviour, like a dog-inspired robot cowering in fear due to being shouted at (Fig. 7). Finally, the new storyboards were designed to combine a traditional storyboard with the 'Animals-At-Risk' thematic apperception test. We found that the themes collated from the data reflected material the designers of the 'Animals-At-Risk' thematic apperception test expected it to elicit, i.e., "attachment, loss, separation, discipline, and conflicts over pet care" [83, p. 67]. For example, three of the children's storyboards centered around reactions to the pet breaking belongings [C5, C15, C21], which is the scenario of a prompt in the 'Animals-At-Risk' thematic apperception test.

5.2.2 Achieving Consensus

We found similarities across the educators and the children, but also differences (Fig. 3). A key challenge for co-design with multiple user groups is achieving consensus and navigating conflicting design requirements. A common approach to achieve consensus involves bringing stakeholders together to discuss and exchange views, which requires careful mediation [125]. This may be especially tricky where there is a power imbalance between the groups (e.g., 'experts' and users, or adults and children) as participants may feel a pressure to acquiesce [126]. Alternatively, consensus can be achieved through sequential design workshops where one group builds on the ideas of the other, like Newbutt et al. [33]. However, this step constrains the second group to the ideas already expressed by the first, and researchers may be less likely to pick up on differences, or indeed similarities, between the groups. While our methodology does not help us to reach consensus at this stage, the mirrored structure and activities of our workshops meant we got the perspectives and designs of both groups, uninfluenced by the other. To extend this work and build a level of consensus, it would be helpful to combine the two groups for discussion. Consensus will not necessarily mean all requirements are satisfied, but instead will mean the final

prototype is satisfactory to all, given the existing constraints [127].

5.2.3 Children's Animal Welfare Knowledge

This group of children demonstrated a solid understanding of animals and animal behaviour. They recognised many of the same aspects as educators when it came to the importance of AWE (Table 2) and the needs of pets. Furthermore, several storyboards gave correct interpretations for the behaviour of common pets and the underlying reason for this behaviour, like a dog-inspired robot cowering in fear due to being shouted at (Fig. 7). However, this level of animal welfare knowledge may be specific to this group of children. Other studies on AWE interventions in a similar region find that 63–67% of children own a pet [34, 56, 128], close to the 71% figure here, but in the sample from Williams et al. [56], only 11% of children owned more than one species of pet, compared to 42% of children in our group. A chi-square independence test showed the variety of pets owned by a child differed significantly between the two samples ($\chi^2(2, N = 147) = 15.1, p < 0.001$) meaning a greater proportion of children owned more than one species of pet in our sample. Owning multiple species of pet could indicate greater interest in animals and thereby potentially greater knowledge than average in our sample. Nevertheless, the designs revealed some gaps in children's understanding; the children's intuition of animal communication was limited to the noises they make, whereas educators included cues from the facial features and tail. Children are more likely to misinterpret dog behaviour when they do not take a full range of cues (movement, posture, sound, face, and tail) into account [129], which can increase their risk of being bitten [130]. Our findings reinforce the work of Muldoon et al. [131] that children are uncertain about identifying behavioural cues and interactive education methods would be helpful.

While the purpose of the workshop was to gather design insights for a zoomorphic robot for animal welfare education, future work could use adapt the workshop activities to become an animal welfare education intervention in and of itself, as with Pons and Jaen [58] and Hirskyj-Douglas et al. [59]. For example, completing the storyboard could help children to reflect on the potential impact of their actions on animal welfare and what could be done differently. Designing a robot could also help children to reflect on key features of animals.

5.3 Limitations and Future Work

The workshops were a one-off, time-limited event, so there was a limit to the activities we could conduct and the data we could collect. In particular, we might have uncovered

other design considerations using methods other than draw-and-write, like low-fidelity prototyping or modelling with plasticine. In addition, the children's workshop took place in an unfamiliar place for them, with unfamiliar researchers, so they may not have felt as comfortable to express their thoughts and feelings as they might have in a school setting or if they had interacted with the researchers before. Lastly, the findings are likely somewhat influenced by the workshop design. For example, the personas presented and the robots demonstrated may have influenced the designs the children and educators produced. An additional workshop using different robots could investigate this phenomenon.

These findings are specific to the country and context (e.g., high income country, high levels of pet ownership, high expressed regard for animal welfare), so it would be good to involve participants from other regions. Furthermore, the children involved were all from one school. Prior research has shown differences in attitudes to animals between adolescents in urban and rural environments [132, 133] (although other studies do not find differences [4]), so it could be beneficial to involve a group from another school in a different area. However, involving another group of participants is unlikely to remove recurrent themes.

The findings for the narrative design provide only an initial flavor of the setting and scenarios for the educational intervention, but defining the structure and events of the story would need further work. A possible extension is running a writing workshop with the two groups to further develop different story ideas when a prototype exists. Future work with the branching storyboard tool could compare it with a plain storyboard by looking at the difference in the number of ideas generated, as in Moraveji et al. [84].

The design insights from the workshops will be used to develop a prototype zoomorphic robot for AWE, focusing on how it can facilitate the learning objectives identified in Table 2. The zoomorphic robot will be developed in tandem with an appropriate interactive narrative and other educational materials. Once developed and refined based on feedback from animal welfare educators and children, the zoomorphic robot will be tested in an in-school AWE program to see if it results in improved learning outcomes compared to existing tools.

6 Conclusion

We conducted two co-design workshops, one with 11 educators from an animal welfare organisation and one with 24 primary school children, to inform the design of a zoomorphic robot and narrative for AWE. Their discussions and designs have highlighted important considerations for the appearance, behaviour, and features of such a robot, including

furriness, negative reactions to undesirable behaviour, and facial features and a tail that can signal an animal's internal state. When it comes to the narrative around a zoomorphic robot for AWE, it is important to consider how to convey changes ("actions have consequences"), balance positive and negative experiences, and frame interactions with the zoomorphic robot. Through conducting separate co-design workshops with educators and children, but mirroring their structure and content, we found key similarities to build on (e.g., pets' use of noises to communicate emotions, a focus on tactile interactions) and key differences to navigate (e.g., the focus on responsibility or fun in pet ownership). In all, this work marks an important step in responding to a call from AWE researchers for more interactive teaching tools [56, 131] and provides insights for designers of other zoomorphic social robots.

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Data Availability The materials used in the workshops and data generated by this research are available online via the Open Science Framework: https://osf.io/zd89e/?view_only=fd944f3a0f3a4da08ee31e8aef749f66.

Declarations

Ethics Approval and Consent to Participate The research protocol received ethical approval from the University of Edinburgh School of Informatics. Educators, children, and guardians received information sheets before the study and signed physical consent forms.

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