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RESEARCH ARTICLE

Parents' epistemic supports during home-based engineering design tasks: opportunities and tensions through the use of technology

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Abstract

Within engineering education, informal, out-of-school making experiences and parent–child interactions within home environments are both considered as a promising context for the development of engineering discourse and practices. However, less is known about how parents support children's engagement in engineering learning, particularly when they are foregrounded with making that use materials and technologies that can introduce sources of uncertainty. To understand both the opportunities and uncertainties of centering making within parent–child engineering learning experiences, this study examines how parents' use of epistemic supports differ between engineering design tasks with technology and engineering design tasks without technology, and within the different phases in the engineering design process. The study further investigates how parents exhibit epistemic uncertainties differently between engineering design tasks. Building on the notion of guided participation to frame engineering learning and making as co-constructed through multiple situated interactions, this study demonstrates that: (a) parents are skilled knowledge practitioners for their children's engagement of engineering learning through the use of various epistemic supports; (b) the presence of technology in the engineering design tasks prompt different types of epistemic practices and engineering design phases; (c) opportunities and tensions co-emerge when parents experience epistemic uncertainty about STEM concepts or troubleshooting during engineering design tasks with technology. We discuss implications for the design of engineering design tasks within home environments that extend the use of parents' epistemic supports.

Keywords Epistemic support · Uncertainty · Engineering · Family learning · Informal education · Emerging technology

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A prevalent issue in engineering education is the lack of representational diversity in terms of who pursues and obtains a degree and career in engineering (National Science Foundation, 2023). Two potential approaches to broadening participation in engineering learning are through making or the maker movement (e.g., Martin et al., 2020), and through the consideration of the role of parents and caregivers. Informal, out-of-school making experiences have demonstrated considerable promise in fostering engineering practices through design and play (Kim et al., 2022a, 2022b; Martin & Betser, 2020; Martin & Dixon, 2016; Simpson & Knox, 2022; Vossoughi & Bevan, 2014). Moreover, such experiences position learners as epistemic agents who can contribute towards creating solutions and shaping the knowledge of a community (Stroupe, 2014), thus broadening the spectrum of who can engage in STEM and what counts as STEM. In continuing this effort to positioning learners to become epistemic agents, we focus on the role of parents and caregivers who can support their children to know and do engineering through various forms of epistemic supports—knowledge claims and questions that parents assert, contest, and defend within interactions with their children (Heritage, 2013). To support parents and caregivers to provide epistemic supports, we provided families with at-home engineering challenges using kits that included simple materials and technology, as well as facilitation guides with question prompts that parents can utilize to engage in engineering learning experiences on their own.

As parents have shown to guide their children in science learning by providing questions, supporting observational practices, and providing explanations to understand science (e.g., Cian et al., 2021; Dou et al., 2019; Doung et al., 2021), we contend that parents and caregivers can employ various forms of epistemic supports with their children at home when they engage in designed engineering learning activities. However, we also recognize that parents and caregivers may not perceive themselves as qualified to contribute to children's engineering learning, especially if the engineering learning involves the use of technology that introduces sources of uncertainty, a "situation in which *knowing* or *what is known* is made problematic" (Umphress, 2015, p. 262 italics in original). This challenge is particularly evident when parents lack prior knowledge or background in STEM and technology, as highlighted in Roque et al. (2016). As such, we conjecture that parents' use of epistemic supports might differ between their engagement in STEM activity with and without the use of technology. Thus, to understand both the opportunities and uncertainties of centering making within parent–child engineering learning experiences at home environments, further research is needed to interrogate the possible tensions that may arise when parent–child engineering learning experiences are foregrounded with making that use both everyday materials (e.g., paper, scissors, recycled materials) and emerging technologies (i.e., conductive tape).

The purpose of this exploratory study was to add to this conversation through examining the following two research questions when parents and children are engaged with engineering design tasks within their home environments: (1) How might parents' use of epistemic supports differ between engineering design tasks with the presence of technology (i.e., tech kits) and engineering design tasks without the presence of technology (i.e., no-tech kits), and within the different phases in the engineering design process? (2) Subsequently, how might parents exhibit epistemic uncertainties differently within engineering design tasks with the presence of technology and engineering design tasks without the presence of technology? Through this study, we argue that parents are skilled knowledge practitioners (Umphress, 2016) within the domain of engineering and making to engage their children in engineering design tasks through various epistemic supports. We further demonstrate that opportunities and tensions co-emerged when families lacked STEM knowledge or experienced challenges with troubleshooting and highlight the importance of remixing different aspects from tech and no-tech kits to cohesively integrate opportunities to engage in different epistemic practices of engineering. We contend that this empirical research is situated within an educational context (i.e., home) and with educators (i.e., parents) that are often overlooked and/or backgrounded; thus, minimizing an environment that is consequential to the growth and development of children. Additionally, this study adds to the scant research regarding parent–child interactions with technology at the intersection of making and engineering within the home environments. Lastly, the results of this study inform design implications or recommendations to support the epistemic supports of parents when engaging their child(ren) in engineering design tasks in their home environments.

Theoretical grounding

Our analytical framework builds on sociocultural perspectives, which view learning as active participation and joint engagement in meaningful cultural and social activities (Mejía-Arauz et al., 2018; Rogoff et al., 1993). In this study, we understand participation as the collaborative engagement of parents and children while exchanging ideas and communicating with verbal and non-verbal means (Rogoff, 2008). This view builds upon the notion of the Zone of Proximal Development as it involves "not only the face-to-face interaction, which has been the subject of much research, but also the side-by-side, joint participation that is frequent in everyday life" (Rogoff, 2008, p. 60). The interactions explored in this study show parents and children working side-by-side while engaging in collaborative and culturally valued activities (i.e., engineering kits) within their home environments. Additionally, we employed Rogoff et al. (1993) guided participation in which children interact and engage with others around them toward a shared goal. Similar to how previous studies adopted guided participation to understand how parents mediate children's participation informal science learning contexts (e.g., Luce et al., 2017; Vedder-Weiss, 2017; Zimmerman & McClain, 2016), this study focuses on the use of epistemic supports as a form of guided participation that parents and caregivers employ to support their children in engineering thinking.

More specifically, this study is guided by Umphress's (2016) work on positioning parents as skilled knowledge practitioners, defined as individuals who are dedicated to supporting, challenging, and enhancing children's knowledge. It is the case that parents and children engaged in "doing knowing" through their shared endeavors. Framed as a dynamic construct, "knowing encompasses all of the ways that knowledge is used, developed, problematized, manipulated, contested, explored, encouraged, and so forth" (p. 329). Knowing often happens through engagement within everyday occurrences and experiences of families (e.g., Goodwin, 2007), or stated differently, through meaningful cultural and social activities (Rogoff et al., 1993). One way this may be highlighted is through posing questions such as "How do you *know*?" or "How are you *thinking* about solving this problem?" (Umphress, 2016). Another is through connecting new knowledge to pre-existing knowledge through shared endeavors such as discussing how a firefly's "lighter" works in relation to what is known about how a flashlight works (Goodwin, 2007). In these cases, parents serve as skilled knowledge practitioners as they find opportunities to engage their children as knowers within their own personal settings and experiences (e.g., home environment).

Relevant literature

We situate this study along three lines of prior research. First, we present research on the ways parents and teachers ground their interactions with children in ways of knowing (i.e., epistemic supports). We included research on both parents and teachers because many adults lack an understanding of the field of engineering (e.g., Zulkifli et al., 2022) and have not been exposed to engineering as a former K-16 student. This prior research highlighted the lack of research regarding parents' epistemic support, but also informed the manner in which we analyzed and interpreted the data (Umphress, 2015). While prior studies on epistemic supports show different ways teachers and parents support children's knowledge construction, most of the studies examined one particularly type of epistemic support, emphasizing the need for a comprehensive study that examines different approaches of parents' epistemic supports. Second, we consider scholarship regarding the role of parents in supporting their children's development as STEM learners. Parents serve as one of their children's most effective and unique educators as they are experts in their understanding of how their children learn, what they are interested in, and prior experiences that are relevant to their learning (Callanan et al., 2017; Goldman & Booker, 2009; Thomas & Anderson, 2013). We highlight that a subset of the literature that focused on the role of parents in supporting children's STEM learning has an overlap with the literature on epistemic supports, particularly when parents supported children to think to define and solve the problems. However, it is challenging to directly make connections to the use of parents' epistemic supports. As such, this body of research informed the interpretation of our results (i.e., discussion), namely how the results are similar to and/or different from prior research that highlights the various instructional approaches that parents use to support the STEM development of their children. Third, we highlight prior research on engineering design processes as this informed the design structure of the engineering tasks and has been acknowledged as part of the making and tinkering process (e.g., Marcus et al., 2021; Wang et al., 2013), particularly when framed within a design challenge or task (Pagano et al., 2019). Further, this decision was to engage families in a process similar to that of engineers (e.g., Atman et al., 2007) and foundational to similar engineering programs in both out-of-school contexts (e.g., Pagano et al., 2020; Tõugu et al., 2017) and in-school contexts (e.g., Cunningham, 2015; Cunningham et al., 2020; Hill-Cunningham et al., 2018).

Epistemic supports

Researchers have examined knowledge construction within social interactions through various epistemic stances such as epistemic agency (Jung et al., 2020), epistemic primacy (Liu, 2023), epistemic authority (Goldman et al., 2021), and epistemic uncertainties (Chen & Qiao, 2020; Umphress, 2015). Within out-of-school learning environments, Ochs's et al. (1989) investigation of cognitive activity through story-telling and Zimmerman's et al. (2008, 2010) characterization of parent–child interactions and epistemic roles in museums have served as foundational examples of this research. In this study, we consider these various epistemic stances as epistemic supports as parents, and teachers, use a wide range of approaches to assist the knowledge construction of a child.

This body of scholarship highlights how parents support their children as epistemic agents by allowing their children to initiate conversations and provide directions (Svarovsky et al., 2018), shifting who has agency from themselves to their children (Jung et al., 2020), and engaging and re-orienting children's unwillingness to participate to one of being playfully engaged (Umphress, 2016). As an example, Jung et al. (2020) examined families' interactions within a making activity focused on invention. They noted a shift from the beginning to the end of the activity as parents often situated themselves as lead inventors at the start of the activity, reading the instructions, and coaching their child to complete the activity (e.g., posing questions, pointing to tools). Yet, by the end of the activity, parents' agency faded while children's epistemic agency increased. They were observed taking control of the inventing and knowledge-building process, highlighting how epistemic agency is an interplay, a negotiation, between parent–child, where equal participation as epistemic agents may be difficult (Liu, 2023). In other words, parents play a central role in determining when and how their children may exhibit different types of epistemic agency or not (Goldman et al., 2021), which is likely informed by parents' own epistemic cognition and/or uncertainties about a particular concept or skill (Brownlee et al., 2017; Starrett et al., 2023). In Umphress's (2015) research, the use of "I don't know" was commonly used by parents within interactions with their children to express a lack of understanding (i.e., epistemic uncertainty), and in doing so, did not allow space and time for their children to contribute or respond and/or do not reach a resolution.

Parents as STEM educators

Parents play a vital role in supporting their children's development as learners (e.g., Callanan et al., 2017), including cognitive, epistemic, emotional, language, and skill development, to name a few. In other words, parents use a variety of approaches to engage and guide their children in learning concepts, practices, and skills; however, these may or may not support the knowledge construction of their children (i.e., epistemic supports). Within the disciplines of STEM, parents' engagement and interactions with their children in out-of-school contexts can have short-term and/or long-term impacts. Short-term and/or long-term impacts include an increase in academic achievement and understanding of STEM concepts (e.g., Ata-Aktürk & Demircan, 2021; Callanan et al., 2020; Jungert et al., 2020; Marcus et al., 2017), development and maintenance of STEM interests (e.g., Dabney et al., 2013; Maltese et al., 2014; Pattison et al., 2020), rise in sense of ability and intrinsic motivation (e.g., De Silva et al., 2018; Mihelich et al., 2016), positive shift in creative and independent thinking (e.g., Ata-Aktürk & Demircan, 2021; Knox et al., 2022), and a higher probability of selecting a STEM career (e.g., Cian et al., 2021; Dou et al., 2019; Puccia et al., 2021).

Short-term and long-term benefits may also be associated with the type of support(s) parents provide their children through their interactions with one another in out-of-school STEM activities. As research has highlighted, parents want to support their children as STEM learners regardless of their own affinity for and self-confidence (or lack thereof) in STEM (e.g., Callanan et al., 2017; Gonzalez-DeHass et al., 2022; Silander et al., 2018). First, parents support their children through talking about STEM concepts in everyday contexts and conversations (e.g., Acosta et al., 2021; Cian et al., 2021; Dorie & Cardella, 2013; Dou et al., 2019). For example, Vedder-Weis (2017) described how the discovery of Citrus Stink Bugs, by her children, led to an hour-long exploration and discussion about insects. Such STEM talks have been shown to influence children's identity in a STEM field positively, as well as informing their decision to pursue a STEM career (Dou et al., 2019; Rodriguez & Blaney, 2021; Vedder-Weiss, 2018). Second, asking questions is another support parents utilize to guide their children as STEM learners (e.g., Duong et al., 2021; Reynolds et al., 2019; Simpson et al., 2022a). As stated by Osborne and Reigh (2020), "question-ing is one of the most important epistemic cognitive acts" (p. 281). Particularly, questions, such as those that promote high cognitive demand, have the potential to invite exploration and understanding of STEM concepts, promote collaboration and co-learning, and problem solving (Duong et al., 2021; Keifert & Stevens, 2019).

Third, parents provide support through grounding their children's STEM engagement in prior experiences and knowledge (Acosta et al., 2021; Riedinger, 2012). For example, Simpson et al. (2022b) described how a parent utilized the actions of a pulley string from a prior trip to the local science museum to enhance the child's understanding of how to create a zipline to deliver a package from one house to another. Such support has been shown to encourage problem-solving performance when creating a prototype (Simpson et al., 2022b; Tõugu et al., 2017) and promote sense-making related to STEM content (Jant et al., 2014; Zimmerman et al., 2010). Fourth, parents may model ways of thinking about a STEM concept or an approach they might take to solve a STEM problem (Jung et al., 2020; Parks & Bridges-Rhoads, 2018). For instance, Goldman and Booker (2009) described how parents modeled a problem-solving process, such as purchasing a prom dress while staying within a budget. In this particular example, the parent modeled how to mentally calculate an acceptable price range of a dress, including the discount and tax.

Similar to the research above, parents have been observed supporting their children as STEM learners through providing words of encouragement, posing questions, finding resources, demonstrating how to operate tools, and offering suggestions when engaged in activities that include technology such as ScratchJr and Cubetto (Govind et al., 2020; Tzou et al., 2019; Yu et al., 2021a, 2021b). In Kim and Zimmerman (2021, 2023), during informal family engineering programs that utilized littleBits technology, parents' questioning and suggestions elicited opportunities for collaborative idea exchange and material tinkering to engage in creative engineering practices. Through an in-depth analysis of one family case, authors also noted parents' equal engagement to tinker with the littleBits technology and observation of how littleBits and everyday materials were adopted differently by others supported the family to expand their exploration space. This may suggest that parents' equal level of engagement and interaction with both technology and non-technology materials may be helpful towards creative engineering practices. Also, Relkin et al. (2020) examined how parents supported their children while engaged in a screen-free robot program, KIBO. In this study, parents provided more cognitive (e.g., asking questions) and affective (e.g., relieving frustration) scaffolds than physical and verbal instruction. As noted by Relkin et al., this may imply that parents value cognitive development more than social well-being or fine motor skills. However, with the increase of digital media platforms, robotics, online coding programs (e.g., Scratch), and electronics (e.g., textiles), research is only beginning to understand the role of such technology within family engagement (Levinson & Barron, 2018), and specifically within instances in which parents express uncertainties in their skills and ability to support their child(ren) (Roque et al., 2016).

Engineering design process

We acknowledge that there is not one engineering design process, but many in which to guide children's and families' process. For example, the Engineering is Elementary (Cunningham, 2009) program builds its curriculum on ask, imagine, plan, create, and improve. Lottero-Perdue et al. (2016) adapted this process for kindergarten students: ask, imagine, try, and try again. As another example, Wang et al. (2013) highlighted how an exhibit at a science museum was designed to support families through the process of (re)design it, build it, and test it. Regardless of differences in terminology and the number of stages of the engineering design process, they are similar in that they provide a developmental-appropriate process that aligns with the process engineers and makers engage with in their work- and making-related experiences (e.g., Liu et al., 2022; Wang, 2014).

Engaging in such a process has shown promise for children in out-of-school and in-school contexts. For instance, using a cluster randomized controlled trial of 604 classrooms, Cunningham et al. (2020) found that children engaged in engineering curriculum design processes outperformed those in the control group on engineering and science content and concepts. Similarly, researchers have found that engineering design activities and processes support children's engineering vocabulary, transfer of engineering skills, and collaboration (Isabelle et al., 2021), computation thinking competencies (Ehsan et al., 2021) and understanding the concept of volume (Park et al., 2018). Children also identified failure as part of the engineering design process (Lottero-Perdue, 2017). Studies have also highlighted how children are likely to spend more time and exhibit more engineer-ing actions and behaviors related to the stages of creating, testing, and redesigning than other stages, such as problem scoping and brainstorming (Marcus et al., 2021; Wang et al., 2013). As noted by Marcus et al. (2021), this led to children including less information about tools and materials and more engineering-related content in their post-narratives.

Methods

In this study, we utilized naturalistic observational methods (Gardner, 2000; Mulhall, 2003; Zahn et al., 2021) to understand the nature of a situation of interest, the epistemic supports provided by a parent when engaged in an engineering design task in their home environment. As stated by Mulhall (2003), naturalistic observations provide "insight into interactions between dyads and groups; illustrates the whole picture; captures context/ process; and informs about the influence of the physical environment" (p. 307). More specifically, our analysis focused on five parent–child dyads engaged in researcher-developed engineering kits that included either a technology or a non-technology component. See Table 1 for dyad information.

As an example of a technology engineering kit, dyads were tasked with the following prompt in the Give a Gift: Light it Up kit, "After exploring and learning about how to create a simple and parallel circuit, create a paper-based gift that lights up. This could be

Table 1 Participant information

Child pseudonym	Grade	Self-identity	Parent pseudonym	Parent career
Amethyst	2	White female	Amy	Care Manager Supervisor
Jameson	3	White male	Lily	Special Education Teacher
Aleena	4	Biracial female	Mia	Program & Services Evaluator
Atalia	4	Biracial female		
Eden	1	White male	Amanda	Children's Hospital Support Staff
Roberto	4	White male	Khun	Science Professor
			Karen	Administrative Assistant

a greeting card, a bookmark, a name tent, a door sign, etc." For this task, dyads utilized conductive tape as the basis for creating their circuit. An example of a non-technology engineering kit, dyads were tasked with designing a prototype of an animal house that will "help stray animals survive extreme weather conditions common to where you live—rainstorms, really hot and really cold temperatures, earthquakes, or tornados." As such, these kits were designed to capitalize upon the overlapping principles and practices of engineering and making highlighted in the scholarship of others (Kim et al., 2022a, 2022b; Liu et al., 2022). Engineering problems were designed as ill-structured tasks that promoted the development of 2–3 solutions and the creation of a variety of prototypes using any materi-als provided in the kit, but also any materials within their home environments (Jang, 2016; Pulgar et al., 2020). Making occurred through the process of combining separate parts and materials to develop a functional prototype.

There was a total of 15 kits, of which seven included a technology component. Each family was allowed to select the kits most interesting to them, and complete them over a 6-month period, approximately one kit per month. See Online Resource 1 for a list of kits and the engineering design tasks that families were asked to engineer a solution for (see our websites—https://athomeengineers.com/—for access to the kits). Each kit was designed to follow an engineering design process—research, plan, create, test, improve, and reflect. Using the Animal House kit noted above, we provide a modified example of how the engineering design process was facilitated within the guide (see Fig. 1).

The kits included one set of instructions for the children and another set of instructions for the parents. In general, parents were encouraged to complete the kit alongside their child(ren), but they were not given any directions, rules, or expectations in the role(s) they should take when interacting with their child. However, the parent, or facilitator guide, included additional support that could be utilized to guide participation while engaged with the child such as optional questions, troubleshooting lists, and background information on concepts such as simple circuits. Examples of this instructional design element for the Animal House are highlighted in Fig. 2.

Data source

The data source for this study was dyad-recorded video data of their interaction around the kits in their home environment. Each dyad had a unique zoom link to record their interactions, which was automatically saved to the second author's secure cloud account. Parents were instructed to record their entire interactions with the kit. Table 2 documents the order of kits that each family engaged, as well as the total length of the video recording for each kit in hours: minutes: seconds.

Although the number of kits and time spent on each kit varied across families, the average time spent per kit regardless of the inclusion of a technology component was similar within families.

Data analysis

Four stages of data analysis were involved: (1) transcription of episodes, (2) establishment of the coding scheme, (3) applying the coding scheme, and (4) conducting data analysis based on the research questions. First, two researchers individually watched each video, documenting verbatim each moment in which a parent used an epistemic support, as well as analytical memos that articulated our understanding of the epistemic marker within the

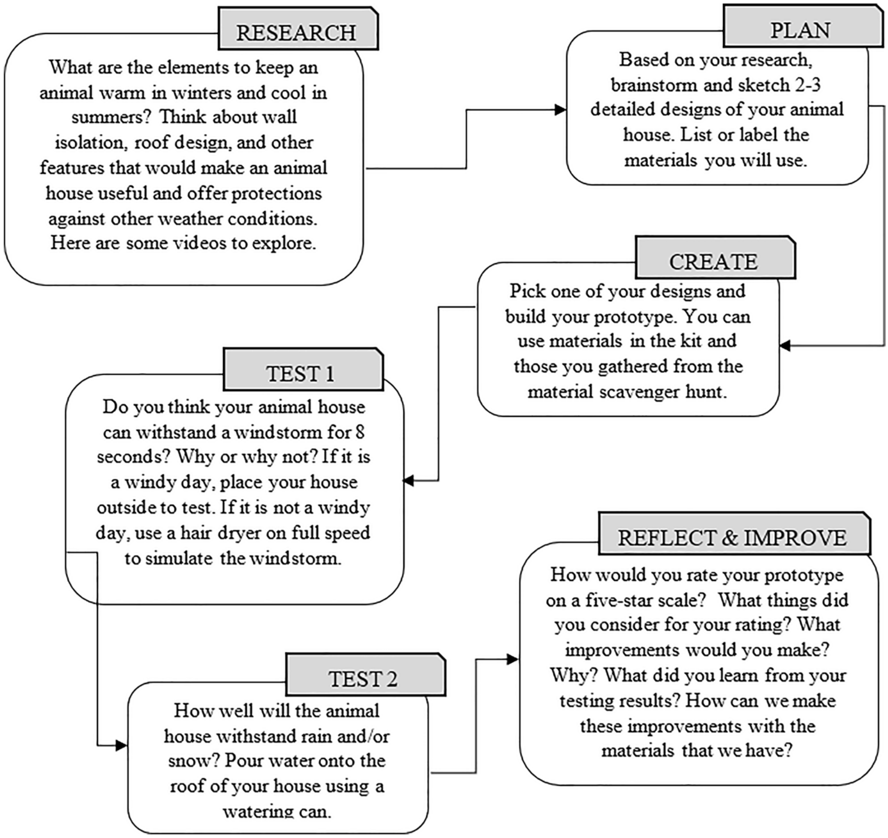

Fig. 1 Example of engineering design process embedded in the kits

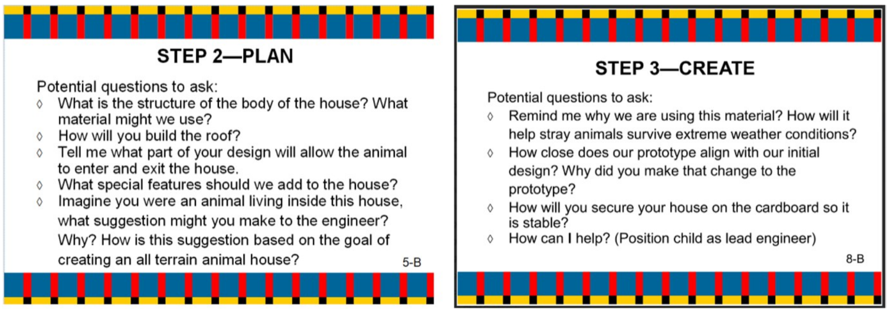

Fig. 2 Examples of support for guided participation within parent–child interactions

engineering design process (e.g., plan) and situated nature of their interactions (Birks & Francis, 1984). These were placed chronologically in an excel sheet (see Fig. 3), and each row included one epistemic marker, such as the use of "I think," "I [don't] know," "do you know," and "I'm [not] sure" (Kaltenböck, 2010; Kärkkäinen, 2010; Lakoff, 1973), as well as hedge words such as "maybe" and "possibly" (e.g., Alqurashi, 2019).

Table 2 Timeline of kits per family

Dyad	Kit 1	Kit 2	Kit 3	Kit 4	Kit 5	Kit 6
Amethyst & Amy	Paper Coaster 2:25:57	Trendy Tennies 1:47:42	Animal House 4:08:14	Give a Gift* 2:41:09	–	–
Jameson & Lily	Rain Gauge* 0:38:57	Watercolor Bot* 0:28:28	Delivery Package 0:26:12	Animal House 0:18:18	Grabber 0:13:30	Toy Hack* 0:11:57
Aleena, Atalia, & Mia	Paper Coaster 1:19:18	Watercolor Bot* 1:27:18	Delivery Package 1:44:57	Animal House 1:09:31	Toy Hack* 0:44:21	–
Eden & Amanda	Rain Gauge* 0:43:58	Delivery Package 0:26:15	Puppy Trainer 0:13:45	–	–	–
Roberto, Khun, & Karen	Blooming Flower 0:48:07	Delivery Package 0:44:01	Joystick* 0:43:43	Rain Gauge* 0:53:01	Trendy Tennies 0:25:08	–

*Indicates kits that include a technology component

	A	B	C	D	E
1		Author 2		Author 1	
2	Timestamps	Description of their behaviors/or transcripts	Memos	Description of their behaviors/or transcripts	Memos
20	18:11	J suggested adding another cotton ball as opposed to starting with a new one. L: That would make it heavy though. J: But it might be too light too. I don't know.	J countered L's statement, but then questioned himself as he expressed doubt in his own thinking. Genuine lack of knowledge.		
21	18:47	L: Maybe we had used too many cotton balls.	Use of "maybe" implies some uncertainty. But I am also wondering if this is used here as a "soft blow" since this was J's prototype with too many cotton balls.	L: Maybe we had used too many cotton balls. J: And then we took away too many.	"maybe" used almost like a suggestion for one of the possible causes for why it didn't work rather than uncertainty
22	20:25	L: And we need to put the motor in here…I think.	Questioning her own understanding (second guessed approach).	L: I think we are out of the tape… J: (gets tape) L: And we need to put the motor in here, I think.	"think" used to share what they notice and provide suggestion.
23	20:58	J: Wait a minute. I think I might need a little bit bigger one [piece of tape]. (added tape) Let's take it off and just do it again.	Seemed somewhat confident in that the size of the tape was too small; realized something was wrong and/or something needed to be changed.	S: I think we might Jeed a bigger one (referring to tape) I think…let's take it off and do it.	Same as above

Fig. 3 Image of analysis in excel sheet

Next, we individually reviewed the episodes from one video and labeled the epistemic markers by the support type (i.e., Is the epistemic marker serving the purpose of challenging an opinion or is it providing a suggestion?). Then, to establish the coding scheme, we met after the analysis of each video to discuss commonalities and differences in what and how we labeled each epistemic marker. Our intent was not to establish inter-rater reliability, but to account for both our perspectives, which serves as a form of investigator triangulation—researchers with different backgrounds and experiences examining the same phenomenon (Denzin, 1984). Initially, our codes included epistemic question, challenge, idea, uncertainty, and authority. However, as we reviewed more videos, we observed the need to add new codes. For instance, we noticed that parents sometimes feigned uncertainty even when they knew a certain concept to prompt the child to explore the engineering concept further. Through discussion, we added another code, "playful" uncertainty, to differentiate from expressing genuine uncertainty. Through this iterative process, we additionally observed the need to sub-categorize epistemic questions into eight question types and epistemic uncertainties into five uncertainty types to allow for a more nuanced understanding of the varied ways each epistemic question and uncertainty was used. Consequently, eight codes for epistemic support and sub-codes for epistemic questions and epistemic uncertainties emerged from our analysis (refer to Online Resources 2 & 3).

The final coding scheme was applied to all the videos. Any uncertainty or disagreement of coding results was discussed. For example, the first author coded the following epistemic question type as material while the second author coded the question type as prototype design: "Oh, it [marble] gets stuck right here. Why do you think it got stuck right there?" The first author considered the response of the child—"the tape"—in this instance, while the second author considered the question to be encouraging the child to think (and eventually improve upon) about a failure moment within the design of the prototype. Through discussion, we agreed that the appropriate code was epistemic question type as prototype design. By engaging in iterative discussion and revision of coding results, we ensured that we had a full agreement between all the coding results. In addition, we also coded each moment of epistemic support to identify when this epistemic support was utilized during the engineering design process (i.e., research, plan, create, test, improve, reflect).

Then, to address the first research question, we individually revisited the Excel sheet that included transcription of epistemic supports with our memos to code them according to the established coding scheme. Given that not all families completed the same kits and the time spent on the kits varied across families, we looked for patterns across families by making comparison qualitatively; the frequency and percentage of epistemic support by type was calculated. When there was a notable difference in the type of epistemic support between the engineering task type, we checked the excerpts of epistemic moments to understand how they were used. Further, the frequency of epistemic questions by their types and the cumulative sum was examined to further interrogate if certain types of epistemic questions were asked more frequently between two different types of engineering design tasks. A similar process of data analysis was conducted to understand if parents' use of epistemic supports differed by the engineering design phases.

To address the second research question, we identified moments of epistemic uncertainties to investigate if and how families' epistemic uncertainties differed by the presence of technology in the kits. Going back to the coding results, we established a narrative account that outlined five dyads' discourse and interaction before and after the moment of epistemic uncertainty. For each moment of epistemic uncertainty, we created an interpretive, narrative account of what is not known to the interactants (source of epistemic uncertainty) and how the family interaction unfolded after they experienced epistemic uncertainty, attending to how the parents or children took up the uncertainty (i.e., rely on instruction, ask questions, positioning certain interactant to provide ideas). Families' interaction around epistemic uncertainties in tech and no-tech kits were compared within and across dyads in qualitative manner. We held data sessions to read each author's narrative accounts. When uncertainties or questions emerged, each families' video was revisited to update the narrative accounts to ensure validity of the accounts.

Results

We report on the challenges and opportunities of including technology in the engineering design tasks as experienced by five family dyads within the home environments. We start by illustrating the overview of the distribution of epistemic supports across five dyads and the overview of epistemic supports in tech kits and no-tech kits by engineering design phases. Next, we demonstrate different ways in which parents took up moments of epistemic uncertainties in tech and no-tech kits. Examples are included throughout to illustrate how epistemic supports were utilized by parents in their interactions within different types of kits.

RQ1: Epistemic supports by tech- and no-tech kits

Broadly, epistemic question, idea, and uncertainty were more frequent across families than epistemic assurance, positioning, challenge, playful uncertainty, and authority. More specifically, the five parents utilized comparatively more epistemic questions and challenges when engaged in no-tech kits when considering the distribution of frequency within each category (see Fig. 4). In contrast, there were comparatively more epistemic uncertainties, ideas, and assurance in tech kits.

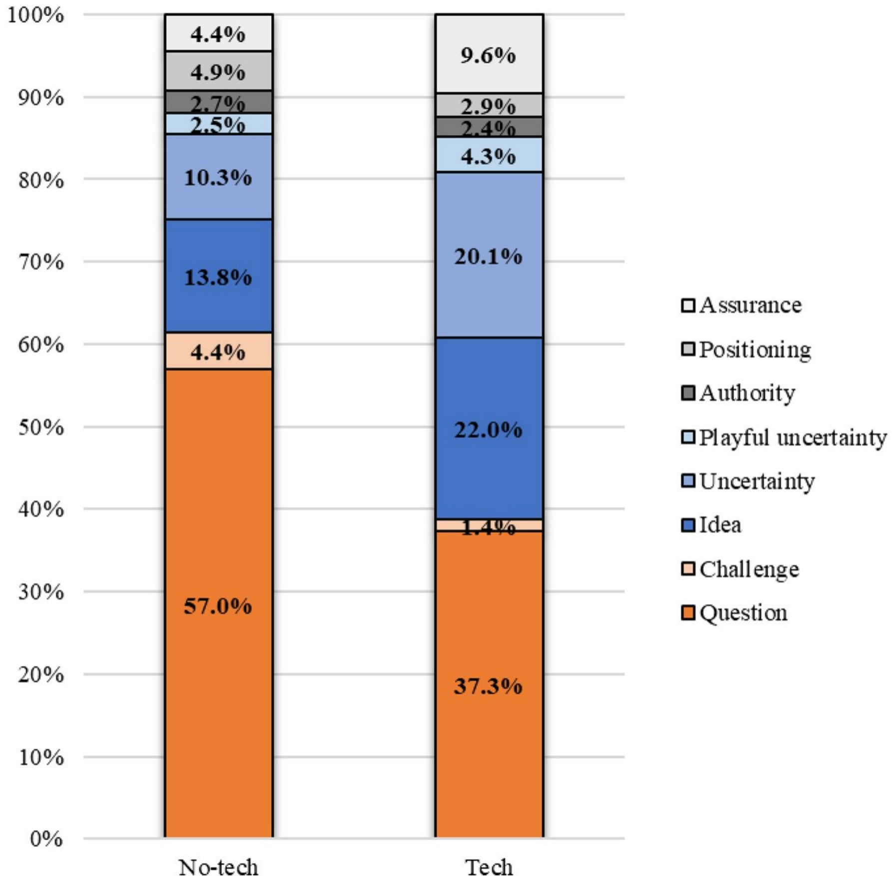

Fig. 4 Percentage of epistemic supports by type in tech and no-tech kits

Epistemic challenges in no-tech kits

Parents more frequently employed epistemic challenges and questions about the design of the prototype in no-tech kits when they anticipated that a different approach or material could support children's creation of the prototype. One such example occurred between Amethyst (child) and Amy (parent) as they worked on the paper roller coaster kit. Amethyst envisioned developing a Barbie-themed roller coaster in the shape of a candy cane. In creating the curve of the roller coaster, Amethyst was focused on the aesthetics of the curve through cutting strips of paper into smaller lengths. Amy, on the other hand, was focused on the functionality and design of the curve through creating what she termed as "wedges" (i.e., bends) within the strips of paper.

1.1 Amy: Do you think you are gonna be able to accomplish that quick curve using this [your] technique? Is it working right now? *(points to curve)*
1.2 A: It's like working.
1.3 Amy: What do you mean by working?
1.4 A: It's getting there but it's not getting there as fast.

1.5 Amy: Okay. Why not?
1.6 A: We are not using the wedge technique?
1.7 Amy: Which you don't want to use.

In Line 1.1, Amy challenged Amethyst's approach to creating the "curve." As observed, Amethyst's addition of small strips of paper was not forming a U-shaped common to a candy cane, but a wide, circular arc more typical of what we see of a rainbow. Amethyst acknowledged that using Amy's wedge approach would be more eficient (Lines 1.4 and 1.6). While Amy disagreed with Amethyst's approach, she allowed Amethyst to continue creating the curve based on the aesthetics of short strips of paper. It was not until they reflected on their experience that Amy illustrated how the wedge would have created a curve that mirrored Amethyst's candy-cane design. Similarly, in other instances in no-tech kits, parents used epistemic challenges when they had certain understanding that alternative options to their child's thinking and approach were available.

Epistemic ideas and assurance in tech kits

While epistemic positioning was more frequently used in no-tech kits, when considering the distribution of frequency within each category of tech and no-tech kits, parents' use of epistemic ideas and assurance was more prevalent in tech kits. Parents in the study posed epistemic ideas in tech kits (22%) than non-tech kits (13.8%) when they experienced challenges in creating the prototype or making decisions regarding how to fix issues following a failure. Using an example from the watercolor bot, Jameson (child) was attempting to keep four cotton balls and eight q-tips together when Lily (parent) posed, "Here, you know what we can do? We can try another rubber band to hold in place." Jameson responded, "Oh, yeah. How about…how about right here?" Jameson indicated to Lily where to wrap the rubber band as his hands were busy holding the bot together. After wrapping the rub-ber band around the bot, Lily noted, "Let's try that and we can move it around." In this example, the use of "you know" sets up a suggestion that Lily and Jameson can consider together. Jameson took up this idea by offering where to wrap the rubber band.

Further, parents were observed providing their children with more epistemic assurances in tech kits (9.6%) than non-tech kits (4.4%). For example, when Amanda and Eden were creating a rain gauge, Eden decided to measure rainfall in centimeters. He was in the process of adding a vertical ruler on the side of the cup, marking each centimeter. The following transcript begins as Amanda noted how the instructions included an example in which the creator of the rain gauge "marked halves" (e.g., 1 ½ inches).

2.1 E: I don't have enough room for that.
2.2 A: No? Okay. I think, I think one by one. You know, it's your cup so-
2.3 E: Let's measure more. (places ruler on the side of the cup, aligned with vertical ruler) It looks like a little bit off.
2.4 A: No. I think...you know the bottom of the cup-
2.5 E: is zero.
2.6 A: No, I think we're good. Maybe. You know measurements are hard to make exact.

In this transcript, we observed two epistemic assurances—Line 2.2 and Line 2.6. In Line 2.2, Amanda assured Eden that the cup is his and it is okay to not mark half centimeters. Further, in Line 2.3, Eden noticed that the distance between each line is not measuring a centimeter. Again, in Line 2.6, Amanda used "I think we're good" to assure Eden that it is okay to not be accurate because exact measurements are dificult.

Epistemic questions in tech and no-tech kits

As observed in Fig. 4, epistemic questions were the most frequent epistemic support across the five parents—57.0% in no-tech kits and 37.3% in tech kits. In considering the type of epistemic questions (see Fig. 5), check-in questions were used frequently in both no-tech kits (36.1%) and tech kits (35.5%). Epistemic check-ins were frequently used during or at the end of an explanation made by the parent to check child's sense making or posed following just-in-time knowledge sharing about an idea or concept that emerged during planning and creation of the prototype. In such cases, children were positioned to become a knower through these epistemic check-ins. In the following excerpt, Amethyst (child) and Amy (parent) are engaged in discussing situations and circumstances they should think about when creating a house for stray animals (no-tech kit). Amethyst's reasoning as to why stray animals do not have babies turned into a knowledge building moment for Amy to discuss that stray animals do have a lot of babies because they did not have someone at home taking care of them.

> 3.1 Amy: Because if you have a pet, you keep them inside usually. Or you take good care of them, like when you walk, say you have a dog, and you go for a walk. When you

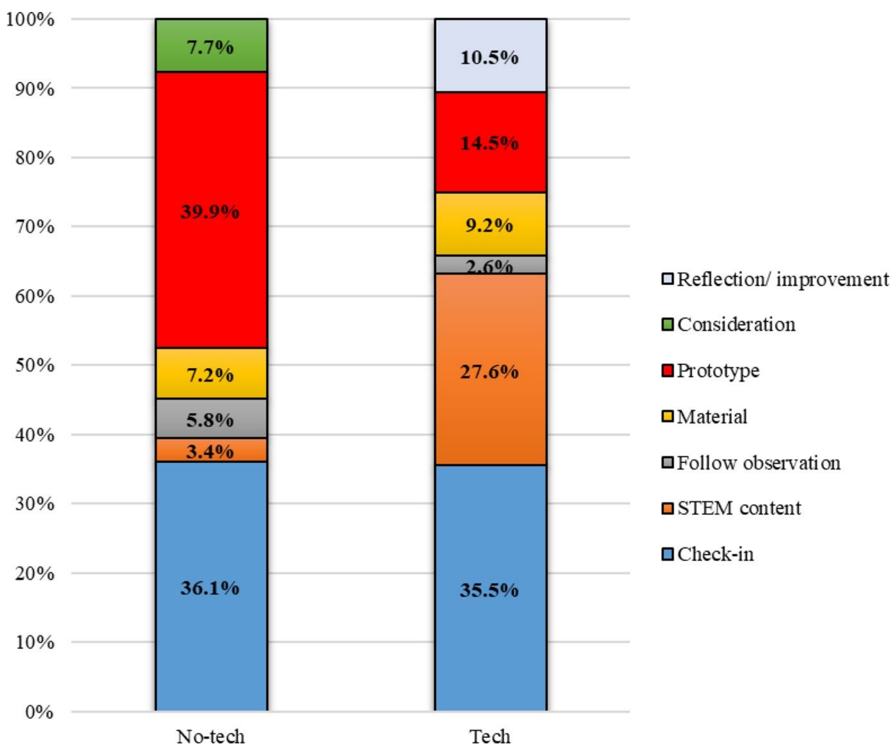

Fig. 5 Percentage of epistemic questions by type in tech and no-tech kits

go for a walk, you don't have the dog go make a baby. Does that make sense? For stray animals, they have no one to say you have to be here. You can do whatever you want. Does that make sense?

3.2 A: Yeah.

After providing an explanation (Line 3.1), Amy followed up with an epistemic check-in question ("Does that make sense?") by asking Amethyst if she made sense of the new information shared with her.

Epistemic check-in questions were also used to gauge children's sense making around new ideas and assess the child's prior knowledge in tech and no-tech kits. In the following example, Alenna, and Atalia (children), and Mia (parent) were using a watercolor bot, a tech kit, and were discussing how to connect a small vibrating motor to a coin battery with the goal of motorizing a bot made from cotton balls and q-tips to paint. The parent asked, "How do you, do you remember when you did…from the open house, how to get the motor to work?" This epistemic question not only grounded Alenna and Atalia's thinking within prior knowledge of a STEM concept (i.e., circuitry), but also grounded in a prior experience (i.e., open house). Later, Mia followed up with other epistemic questions to focus on making an appropriate connection between the battery and the wires of the motor. As such, our analysis showed that five parents used epistemic check-in questions frequently in both tech and no-tech kits to ground their children's engineering learning experience in prior experience and gauge their sense making around new concepts.

In no-tech kits, parents asked more epistemic questions about the design of the prototype. Consider an example from Khun (parent) and Roberto (child) as they developed a way to deliver a package from their house to their neighbor's house. Khun posed a question that encouraged Roberto to consider an alternative design for a basket, "Can you think of another way to do it?" This provided Roberto with an opportunity to continue brainstorming another solution to his original solution of crisscrossing paperclips. "We can use pipe cleaners to tie it around." Further, as Roberto began creating the basket prototype using pipe cleaners, Khun posed a question that encouraged V to consider his design in relation to the engineering task itself. "Do you think that will hold this [toy animal]?" Roberto confidently stated "yeah."

We also observed that epistemic questions about design considerations (i.e., customer, context) were only asked during the use of no-tech kits; however, this was only observable in Amy-Amethyst dyad. In the planning stage of creating Trendy Tennie shoes for Olaf, Amy (parent) asked Amethyst (child), "What do we know about Olaf?" Amethyst read what we included in the instructions regarding Olaf. Amy followed up with, "Okay, that's what we know from here [the instructions]. What do we know from the movies? What do you know about Olaf?" Amy asked a series of questions to help Amethyst think about the needs of the customer, in this case Olaf, to reflect those considerations in the design of the prototype. However, there were no epistemic questions about the design considerations during the use of tech kits.

On the other hand, parents asked more epistemic questions about STEM content and reflection/improvement in tech kits (see Fig. 5). Instead of asking epistemic questions to support the design of the prototype, parents asked more epistemic questions to elicit STEM knowledge and/or involved their children in reflecting about the engineering design process and ways to make improvement on the prototype (e.g., "What did you learn from your research?" "Why wasn't this one working? What do you think?"). To illustrate, consider the following transcript between Khun (parent) asked Roberto (child) as they are discussing properties of materials utilized in creating a rain gauge.

4.1 K: Do you know of other materials that would conduct electricity?
4.2 R did not respond.
4.3 K: Do you know of materials that do not conduct electricity?
4.4 R: I was thinking cardboard at first. I was thinking of a paper towel and a napkin too.
4.5 K: Okay. What about aluminum foil makes you think about the word conductive? Do you know what conductivity means? It means that it allows electricity to flow.
4.6 R: Metal
4.7 K: Yes, it's a type of metal but can you use all metals?
4.8 R: Yeah, like copper.

In Lines 4.1, 4.3, and 4.5, Khun's epistemic questions are grounded in science principles regarding materials that are and are not conductive. Khun funneled his questions to elicit correct responses as this would affect the design of the rain gauge and whether it would function or not. As such, Roberto was able to provide examples that indicated his understanding of the different types of materials that would allow electricity to flow versus those that would not.

RQ1: Epistemic supports by engineering design phases in tech and no-tech kits

Our analysis of epistemic support by engineering design phase in tech and no-tech kits demonstrated that tech and no-tech kits supported parents in opposing ways in their use of epistemic supports. Parents' use of epistemic supports in no-tech kits was highly visible in the plan phase, and less visible in test and improve phases. However, the opposite trend was observed in tech kits in which parents' use of epistemic supports was more dominant in create, test and improve phases, and lacked its visibility in the plan phase when compared to its distribution in no-tech kits (see Fig. 6).

In no-tech kits, parents continuously utilized epistemic questions throughout the engineering design phases, except for the test phase (2 instances out of 231). In fact, except for the test phase, over 50% of epistemic supports within each design phase observed were epistemic questions. However, in tech kits, the percentage of epistemic questions posed by parents within the category of each engineering design phase decreased, except for the reflect phase when the use of epistemic questions suddenly peaked. Findings showed that six out of eight instances of epistemic questions during the reflect phase in tech kits related to improvement and reflection.

Notably, parents utilized epistemic ideas—providing a suggestion, a possibility, or a recommendation—more frequently in test, improve, and reflect phases in tech kits. For instance, during the use of the rain gauge by Roberto (child) and Khun (parent), Khun stated,

> Okay. I'm going to think about switching the paper clip. I am going to go get one of my paper clips. I don't think this paperclip- the way this paperclip is shaped on the bottom with all these dimples and dots, I don't know if it's not losing electrical current.

In this instance, Khun offered a possibility to explore, using a different paper clip that was not dimpled. He hypothesized that this feature of the paper clip impacted the electrical current so that the rain gauge would not light up.

While epistemic challenges were utilized by parents across different engineering design phases in no-tech kits, parents' use of epistemic challenge was lacking in tech

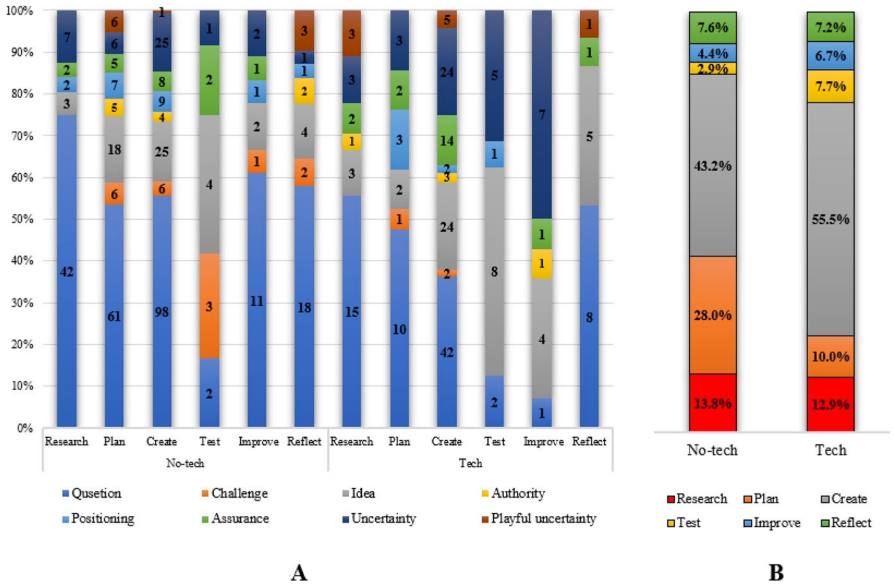

Fig. 6 Counts of epistemic supports by type in each engineering design phase in tech and no-tech kits (**A**) and distribution of epistemic supports and tech and no-tech kits (**B**)

kits during test, improve, and reflect phases. An example of this within a no-tech kit was provided above with the episode of creating a wedge in the creation of a paper roller coaster between Amethyst (child) and Amy (parent). Lastly, epistemic assurance and positioning were slightly more visible in tech kits during plan and create phases. When Amanda (parent) and Eden (child) were creating the rain gauge, Eden noticed that the plastic cup had line markings that were evenly distributed by 1 cm each. Amanda acknowledged, “It did have markings.” She continued “I didn’t know that. I think that’s pretty amazing that you were able to spot that.” As Amanda acknowledged her lack of knowledge in regard to the cup and how it had cm markings, she also declared that Eden’s ability to notice the cm marking was “pretty amazing” and provided praise.

RQ2: Epistemic uncertainties in engineering design tasks

Our analysis further demonstrated that families’ interaction around moments of epistemic uncertainty differed between tech and no-tech kits. As observed in Fig. 6A, parents’ epistemic uncertainties decreased more rapidly after the create phase in no-tech kits. For instance, the occurrence of epistemic uncertainties in the create phase (n = 25) decreased to four in test-improve-reflect phases in no-tech kits. However, the occurrence of epistemic uncertainties in the create phase (n = 24) remained in test-improve phases in tech kits (n = 12). We present several vignettes to demonstrate different ways in which parents addressed troubleshooting and knowledge-based uncertainties in tech and no-tech kits. We further report on the challenges and opportunities these epistemic uncertainties provided for families within their engineering learning experiences.

Troubleshooting uncertainties in tech kits

Troubleshooting uncertainty was a unique type of uncertainty that was mostly observed only in tech kits (i.e., it occurred only once in no-tech kits). In two family cases, troubleshooting efforts were led completely by the parent without much involvement from the child. One such example occurred in Khun (parent) and Roberto (child) when they experienced multiple failures in making the rain gauge light up. When the prototype did not work again after checking all the steps in the facilitation guide, Khun expressed his confusion multiple times: "I don't know because the bottom one worked. I'm confused." Khun shared his thinking aloud and tried to seek the child's understanding of his approach, as he asked: "You know what? I'm going to put the clip directly into the water without the paper clip to see if it will work. Do you know what I'm saying?" As the entire episode of troubleshoot-ing was handled by Khun, Roberto sat next to the parent without having hands-on interac-tion with the tools. This pattern of interaction was also observed in Amy and Amethyst family when Amy asked the child to provide her space so she could troubleshoot why one light in the series circuit was not working on her own. In these instances, parents seemed to take priority in fixing the issues rather than working alongside their children. When par-ents' troubleshooting efforts did not lead to fixing the problem, parents' frustration became more visible, and children were either not present or seemed to have lost interest in troubleshooting the issue.

In other cases, the child suggested ideas to the parent for troubleshooting which were either taken up or dismissed by the parent. For instance, Lily (parent) and Jameson (child) were lacking knowledge as to why their watercolor bot did not work. Jameson suggested, "I have a really good idea. Maybe we can pretend these wires are whiskers for… Is this how we do it [connect motor to battery], mommy?" Lily stated her understanding of circuity is limited and she is unable to find any direction from the facilitator guide: "I honestly don't know. There's not, I can't find directions." Even after multiple attempts, this family did not get the watercolor bot to move and the parent expressed frustration as they did not find new ways to troubleshoot. At the end, the parent suspected the bot might be too heavy and hedged that they stopped trying to make it move.

Knowledge-based uncertainties in tech kits

Our analysis illuminated moments of knowledge-based uncertainties often became episodes of co-learning, in which the parent and the child learned something new, and experimentation to test out their ideas in tech kits. For instance, when Jameson (child) and Lily (parent) were creating a rain gauge, Lily checked the image of the alligator clips in the instruction to learn how they hook up the alligator clips to the battery pack. At this point, she attended to the color of the alligator clips in the image and picked up a misunderstanding that the color of the alligator clips would play a role. As Jameson noticed his mother was unsure of how to create a circuit, Jameson suggested, "How about we try a new paper clip? I think maybe something's wrong with that." Lily then took up his suggestion and noted that the problem was whether alligator clips were hooked up appropriately with negative and positive sides and not based on the color. "Yeah, I had these [alligator clips] mixed up." Consequently, parents were frequently able to acknowledge their own epistemic uncertainties and learn something new by taking up suggestions from their children, and vice versa for children who learned something from their parents.

Parents also showed openness to considering their children's opinion by encouraging them to experiment with their idea and see how it unfolds. Consider the following example in which Aleena (child) asked for Mia (parent)'s help as they were troubleshooting how to get the motor to vibrate in creating the watercolor bot.

5.1 A: Do you know how to do these? *(hands battery and motor to Mia)*
5.2 M: No. I don't. I thought you had it going.
5.3 A: I did, but I can't keep it going, like it would stop, and I don't know what position it was in. Maybe both of them were touching, I don't know.
5.4 M: Umm-hmm. Experiment and see!

After experiencing a failure, Aleena asked if Mia knew how to fix the issue since she experienced the motor stop vibrating (Line 5.1). Mia acknowledged her lack of knowledge in circuitry to make the watercolor bot vibrate (Line 5.2). When Aleena explained that the prototype stopped working and she does not know how to fix it, Mia suggested Aleena to keep experimenting and find out (Line 5.4). In this regard, parents leveraged epistemic uncertainties as resources for learning and experimentation in tech kits.

Knowledge-based uncertainties in no-tech kits

While families also lacked STEM knowledge in no-tech kits (e.g., relationship between Celsius and Fahrenheit), other areas of knowledge related to uncertainty about the non-STEM terminology (e.g., permafrost) in the instructions and uncertainty about the design considerations. In no-tech kits, when knowledge-based uncertainties emerged, parents provided brief explanation based on their knowledge to support child's understanding and prompt further discussion. Often, parents' explanations included some degree of uncertainty. For instance, Amethyst (child) wondered what permafrost is, which was a terminology provided in the facilitator guide. Amy (parent) explained, "A layer of permanently being frosted, I guess?" When uncertainties came from the parents, one parent read about the uncertain terminology using the resources in the facilitation guide and positioned the child to share knowledge.

Discussion

We began this exploratory study by suggesting that parents can be appropriate and effective facilitators for children's engineering learning by grounding their children's engagement in epistemic supports that draw on shared experience, familial knowledge, and culture within the family. We also suggested that while families are a fruitful context for engaging in engineering learning, there may be tensions and challenges when engineering learning experiences are foregrounded with technology as it can introduce sources of uncertainty. Building on sociocultural perspectives and the notion of guided participation to frame engineering learning and making as co-constructed through multiple situated interactions (Rogoff, 2008), our study demonstrated that: (a) parents are skilled knowledge practitioners for their children's engagement of engineering learning within the home environments through the use of various epistemic supports; (b) the presence of technology in the engineering design tasks prompt different types of epistemic practices and engineering design phases; (c) opportunities and tensions co-emerge when parents experienced their own epistemic uncertainty about STEM concepts or troubleshooting during engineering design tasks with technology.

Our study findings highlight the role of parents as already having the resources and potential for engineering educators and learners themselves. Many parents may feel inadequate to engage their children in engineering conversations and interactions (e.g., Gonzalez-DeHass et al., 2022). However, across all five dyads, parents were skilled in providing and transitioning between different epistemic supports regardless of the inclusion or exclusion of technology in the engineering design tasks. Although the most frequently utilized type of epistemic support differed between engineering design tasks that included technology and engineering design tasks that did not include technology, all parents grounded their children's engagement in engineering learning through epistemic check-in questions, which is similar to the use of prior experience and knowledge in how parents supported children's STEM engagement (Acosta et al., 2021; Riedinger, 2012) and promoting sensemaking related to STEM content (Jant et al., 2014; Zimmerman et al., 2010). These epistemic check-in questions were brief, however they served to establish a shared understanding to proceed with the engineering design task. As the engineering design task progressed, parents modeled experimentation and critical thinking through posing epistemic questions. This finding is consistent with prior literature on questioning as an important epistemic move to support children as STEM learners (Reynolds et al., 2019; Simpson et al., 2022a), as they promote exploration, collaboration, problem-solving and co-learning (Duong et al., 2021; Keifert & Stevens, 2019).

Importantly, our study sheds new light on the understanding of parents' role in guided participation (Rogoff, 2008; Rogoff et al., 1993) for engineering learning by highlighting epistemic challenges and playful uncertainty as important epistemic supports that parents employed to encourage the child to consider alternative viewpoints and investigate a certain concept or phenomenon more deeply. The use of epistemic challenge and playful uncertainty is similar to the case of *manipulating epistemic authority* in Umphress (2015) where the mother diminishes the relevance of her own epistemic authority and elevates the relevance of her daughter as a knower by setting the affective tone of the interaction. This kind of "playful" or "manipulative" uncertainty leverages the uncertain moment as resources for further learning and positions the child learner as the knower with authority to construct knowledge. Based on our findings, we advocate for future investigation to understand the full use of epistemic playful uncertainty and epistemic challenges and their outcome for the parent–child's engagement in "doing engineering." Although this study did not investigate the short- and long-term benefits of parents' epistemic supports, in alignment with how everyday science talk in home environments is predictive of STEM identity in college (Dou et al., 2019) and how talking about science with parents at home, regardless of parents' science capital, reinforced learners' STEM identity (Cian et al., 2021), we posit that parents' use of epistemic supports as a form of guided participation (Rogoff et al., 1993) can be one way to diminish the lack of representational diversity in STEM.

The different—sometimes, opposite—types of epistemic practices and engineering design phases noted in our findings indicate that the presence of technology in the engineering design tasks played a critical role. We observed that engineering design phase in which parents' use of epistemic support was comparatively high in no-tech kits was comparatively low in tech kits (i.e., plan), and engineering design phases in which parents less frequently used epistemic supports in no-tech kits were high in tech kits (i.e., test, improve). Building on our findings, we suggest that when an engineering design task involves the use of technology or a component that opens up problem-solving more complicated than what a family is used to, families may likely engage in engineering practices of testing and improving. On the other hand, an engineering design task with familiar concepts and materials may support parents to spend more time with their epistemic supports during the planning phase. Previous studies highlighted how children spent more time engaging in engineering actions during create, test, and redesign stages in open-ended museum exhibits that did not include technology (Marcus et al., 2021; Wang et al., 2013). Since these stud-ies examined the time spent by the children and engineering behaviors rather than parents' use of epistemic practices during different engineering phases, it may be dificult to make relevant connections with prior literature. Thus, future research should investigate how differences in the engineering design task (i.e., level of dificulty, presence of technology) influences families' engagement in engineering design phases differently.

Furthermore, our findings provide a new perspective on the design of the engineering design task and reveal that opportunities and tensions co-emerged when parents experienced their own epistemic uncertainty about STEM concepts or troubleshooting dur-ing engineering design tasks with technology. While previous studies demonstrated how parents supported their children as STEM learners within tech-integrated STEM learning environments (e.g., Kim & Zimmerman, 2021; Govind et al., 2020; Relkin et al., 2020; Roque et al., 2016; Tzou et al., 2019; Yu et al., 2021a, 2021b), parent–child interactions in these studies were framed as parental supports rather than epistemic supports towards knowledge development. The approach taken in this study allowed for an examination of parents' epistemic supports and how they differed by the presence of technology in the engineering task and adds to the scant research on understanding the role of technology within family engagement when they experience uncertainty (e.g., Roque et al., 2016). Our findings showed that while STEM knowledge-based and troubleshooting uncertainties brought frustration, moments of epistemic uncertainty in tech kits were often turned into co-learning moments as observed in many family dyads. Parents were also observed asking more questions about STEM content and engaging their children with testing and improving phases in tech kits as they experienced epistemic uncertainty even after creating the prototype. Certainly, these different types of epistemic practices that parents were more inclined to use in tech kits bring opportunities for revisiting and mastering a STEM concept—to the point that they can apply the concept to create a functional prototype. Moments of uncertainty with technology also opened up opportunities for experiencing "failure" and prompted families to engage in iteration, which is an important process for professional engineers. However, our findings also noted that tensions co-emerged around moments of epistemic uncertainty, particularly when parents focused on fixing the problem too much that they may have pushed their children on the periphery as observers rather than knowers and doers of engineering. As such, this study highlights a previous unexplored aspect of potential tensions and challenges of foregrounding technology in the engineering design tasks for families to work on their own—without educators and facilitators—within their home environments. Future studies need to investigate how these tensions may problematize, hinder, encourage, or develop "doing knowing" together through intergenerational interactions during a mutually-involved joint activity.

Implications

The notion of acknowledging parents as educators and leveraging the family interactional capital as important learning resources is applicable to a range of informal learning environments. Importantly, this study highlights the need to provide different types of support and guidance for parents that extend the use of parents' epistemic supports during engineering design tasks that include technology. Our findings suggest that parents who are not familiar with STEM concepts may experience more challenges to navigate epistemic uncertainties during their engagement with tech kits. As demonstrated in previous literature (Brownlee et al., 2017; Starrett et al., 2023), parents' own epistemic knowledge and/or uncertainty about a particular concept seemed to determine when and how parents employ playful uncertainty and epistemic challenges. For instance, as in the example of epistemic challenge from Amy and Amethyst, parents often provided suggestions up front through epistemic challenges when they had the knowledge to anticipate that certain design choices (i.e., quick turn in the paper roller coaster) would not lead to a successful prototype in no-tech kits. In contrast, we observed evidence that parents' epistemic uncertainties during tech kits sometimes positioned them as the knower and problem solver to take priority in fixing the problem without involving the child in the process.

In connection with Marcus et al. (2017) who demonstrated that parents could support children's transfer of STEM learning when they received engineering information prior to engaging in building-construction activity with their children at a museum, the facilitation guides provided in at-home engineering design tasks could front load parents with engineering and/or technology-related content. For instance, it could include information or digital resources that provide adequate support that they can leverage to manage troubleshooting and knowledge-based uncertainties. Instructions could inform parents that they may experience more uncertainties due to technological components included in the tasks and assure them frustrations and challenges are an important part of the learning process. It may be also important to include specific examples of how parents can provide epistemic positioning and playful uncertainty during engineering design tasks with technology. Similar to how teachers perceive epistemic uncertainty as undesirable for learning and need further support to recognize epistemic uncertainty as a pedagogical resource (Chen & Qiao, 2020), our findings point towards the need for future research on developing supports for parents to embrace their children's and their own epistemic uncertainty. Communicating to parents that they already have the assets and resources and already support their children as engineer learners could be the start.

Finally, as a result of our findings, we see potential in remixing and reconfiguring different aspects from tech and no-tech kits to cohesively integrate opportunities to engage in different epistemic practices of engineering. We illustrated that nuanced differences of parent's use of epistemic supports emerged in tech and no-tech kits, such as: (a) to co-construct the prototype, parents more frequently utilized epistemic questions related to the prototype design while they utilized questions about STEM content and reflection and/or improvement in tech kits; (b) to encourage exploration, parents utilized epistemic challenges in no-tech kits while they utilized epistemic ideas more frequently in tech kits; (c) to provide encouragement, parents more frequently utilized epistemic positioning in no-tech kits while they utilized epistemic assurance in tech kits. In our analysis, we saw opportunities and tensions in family interaction when the presence of technology introduced challenges around learning conceptual knowledge of engineering and troubleshooting. While knowledge-based and troubleshooting uncertainties brought tensions around who took over the troubleshooting process (i.e., epistemic agency), it was also a co-learning moment to understand a new engineering concept. Likewise, in no-tech kits, we noted that there were abundant opportunities for parents and children to carefully plan and brainstorm ideas as they felt comfortable working with familiar materials and concepts. However, we did not frequently observe deep discussion or new conceptual learning around STEM concepts in no-tech kits. Rather than understanding the affordances of each type of engineering design task in dichotomy, future designers and researchers of at-home engineering design tasks could consider remixing craft-oriented and tech-oriented elements to support families to engage in both tangible and conceptual aspects of engineering.

However, the study has several limitations. One of the primary limitations is the small number of participants. The sample used in this study is not representative of the general population, and thus this study's findings are not generalizable to a larger population. However, we note that the purpose of this study was not to establish generalizability but to establish a grounding (Eisenhart, 2009) to continue the investigation of the role of parents as skilled knowledge practitioners in children's out-of-school engineering learning. Another limitation is the difference in the number of children present within each family which could have influenced the family interaction and parents' epistemic supports. For instance, Mia's family had twins collaboratively engaged in engineering design tasks. We noticed that there was less parental involvement within a few engineering design tasks as the parent let two children take the lead and collaborate amongst themselves. We also note that many parents in this study were mothers. Investigation of the type and distribution of epistemic supports between engineering design tasks with different technologies should continue with a broader scope of genders and ethnicities in the participant population. In future research, we plan to investigate whether parents' epistemic supports change over time in their distribution and frequency as parents and children experience more engineering design tasks and participate further in our future engineering activities.

Conclusion

In considering the issues of equity in terms of who participates and pursues STEM learning, understanding the role of parents and caregivers can be one way to tap into an educational context (i.e., home) with educators (i.e., parents) that are overlooked to support diverse learners' participation in engineering learning. Ultimately, this study presents that parents are able to engage their children in discourse and interaction of engineering through the use of epistemic question, challenge, idea, uncertainty, playful uncertainty, authority, positioning and assurance. Furthermore, this study demonstrates that the frequency of epistemic supports differs depending on the type of technology used in the engineering design tasks (i.e., craft material vs. electronics) and provides suggestions that can be embedded within the design of the engineering design tasks. Our work contributes to more impact-ful methods of incorporating parents into the STEM learning process by demonstrating parents as skilled knowledge practitioners within the domain of engineering and making. This study is significant as it begins to fill the literature gap in understanding parent–child interactions with technology in making and the role of parents in supporting at-home engineering learning. With a growing interest in making and increasing recognition of the educational context of home environments, this study informs future scholars and practitioners with practical implications for the design of engineering design tasks within home environments that extend the use of parents' epistemic supports.

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Data availability Identifying information might be removed from identifiable private information and, after such removal, the information could be used for future research studies, but only studies in which the authors are involved.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study was approved through the Institutional Review Board. All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in this study.

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