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Designing culturally situated playful environments for early STEM learning with a Latine community☆

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ABSTRACT

Children from underserved, minoritized, and immigrant families have less access to early out-of-school STEM learning opportunities. Playful Learning Landscapes increase the accessibility of early STEM learning in everyday public spaces (e.g., bus stops, grocery stores) by merging principles of guided play and STEM learning goals with local community's values. We used community-based design research to (1) identify Latine families' funds of knowledge related to play, science, and math learning, and (2) create designs for playful environments merging families' values and practices with guided play and STEM learning principles. Our design partners were 32 parents, primarily Spanish-speaking immigrant mothers from Mexico, and two directors of a local community organization. The design process consisted of co-design sessions, interviews, inductive thematic analysis, elaboration, playtest and feedback, and iteration. Our findings showed that *familismo*, heritage representation, and the meaning of community spaces influenced the ways families engaged in STEM learning and the learning environments they desired in their community. Moreover, families' STEM practices were rooted in everyday experiences of playing cultural games, family food routines, and outdoor activities. Incorporating Latine parents in the design process and leveraging their funds of knowledge resulted in culturally situated designs aligned with playful and STEM learning principles. This study contributes to knowledge of Latine families' values and practices that can help create home-community connections to strengthen children's learning.

1. Introduction

Creating playful learning environments outside of school is a powerful way to support children's early Science, Technology, Engineering, and Mathematics (STEM) learning (Acar, 2014; Hassinger-Das et al., 2018; Hurst et al., 2019). Playing at home and outdoors are central activities in early childhood across countries (Bornstein & Putnick, 2012) that support children's social and cognitive development (Duncan & Tarulli, 2003; Hirsh-Pasek et al., 2020; 2022). Other outside of school activities, like cooking and visiting museums, nurture children's mathematical and scientific thinking (Gaudreau et al., 2021; Geerdts et al., 2015; Pattison et al., 2016) and can foster playful interactions guided by experienced peers or adults. Guided play enables practices like questioning and explaining thought processes that further deepen children's STEM learning compared to free play (Weisberg et al., 2016; Zosh et al., 2018).

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Latine and other historically marginalized children, particularly from underserved families, have less access to rich, playful environments for STEM learning. For example, they have less access to parks, playgrounds, museums, and science centers in their neighborhoods, which may limit their STEM experiences (Dai, 2011; Jones et al., 2015; Mardis, 2013; Wen et al., 2013). Further, cultural mismatches between their learning approaches and values and the ones upheld in those spaces represent barriers to participation, especially for immigrant families (Stein et al., 2008). Leveraging Latine families' cultural assets (e.g., strong social and moral development, community-orientation; Carlo & Padilla-Walker, 2020; Garibay, 2009) in the design of STEM programs can increase the accessibility and inclusivity of opportunities for early STEM learning (Belgrave et al., 2022; Garcia et al., 2022; Leyva et al., 2021).

Playful Learning Landscapes (PLL) is an international movement adopting community-based design research (CBDR) to transform everyday public spaces (e.g., bus stops, grocery stores) into accessible and inclusive playful learning hubs (Bustamante et al., 2019; Hassinger-Das et al., 2018). Guided by cultural microsystem theory (Vélez-Agosto et al., 2017), playful learning principles (Hirsh-Paseket al., 2020), and funds of knowledge (FoK; Moll et al. 1992) theories, we identified immigrant Latine families' values and practices across the home and community contexts to leverage in the co-design of PLL installations for early STEM learning. This study advances knowledge on the math and science practices of parents from underserved Latine families, largely unexplored outside of school (e.g., Galindo et al., 2019; Leyva et al., 2018). Such knowledge also includes Latine parents' values in playful family interactions. We also describe a design process for creating culturally situated playful learning environments that align community funds of knowledge and research on children's learning.

1.1. Playful STEM learning in community spaces

Cultural microsystem theory stresses the central role that culture plays in the daily practices of social communities rather than being a separate entity operating at the macrosystem level (Vélez-Agosto et al., 2017). Culture is situated in the middle of the model and permeates proximal and distal settings in relation to the child, such that families, schools, neighborhoods, and so on represent cultural practices that interact to affect and shape human development. From this perspective, all practices are cultural in nature. Therefore, how families engage in play and STEM learning across contexts are cultural practices that impact children's development. Furthermore, cultural practices in informal settings are emphasized as imperative in children's STEM education ecosystem (Bell et al., 2016), given that children spend 80% of their waking time outside of formal education settings (Meltzoff et al., 2009).

Outdoor play and other informal learning experiences outside of school promotes children's STEM interest (Campbell et al., 2018; Speldewinde & Campbell, 2021), approaches to learning (Bustamante et al., 2018), and high-quality parent-child interactions conducive to STEM learning (Gaudreau et al., 2021; Haden, 2010; Leyva et al., 2021). For example, parent-child conversations at museums and zoos are often imbued with language like explanations and predictions (Gaudreau et al., 2021; Geerdts et al., 2015; Haden, 2010) that cultivates skills aligned with national standards for science and math learning (NRC, 2012; Richland & Begolli, 2016). Children's play guided by more advanced play partners and with explicit learning goals (e.g., *guided play* and *games*) are particularly effective in supporting math and science content knowledge (Habgood & Ainsworth, 2011; Fisher et al., 2013; Ramani & Siegler, 2008, 2011). Guided play and games naturally incorporate characteristics of *how* children learn best – social, actively engaging, iterative, meaningful, and joyful – and promote skills of *what* children need to develop to thrive – content knowledge, collaboration, communication, critical thinking, creativity, and confidence (Hirsh-Pasek et al., 2020, 2022; Weisberg et al., 2016). However, how families engage in play depends on parents' cultural schemas of play (Fleer, 2008; Gaskins, 2015), affecting children's play patterns and partners (Farver & Howes, 1993; Kazemeini & Pajoheshgar, 2018; Parmar et al., 2004). Thus, it is crucial to understand the cultural beliefs, values, and practices of marginalized communities around play instead of privileging western, educated, industrialized, rich, and democratic (WEIRD; Henrich et al., 2010) values and practices.

Cultural relevance is of utmost importance in creating inclusive STEM learning environments in community spaces (Hurst et al., 2019) because misalignments result in missed learning opportunities (Vélez-Agosto et al., 2017). Traditionally, institutions of informal learning align with the practices and norms of "expected" visitors, often leaving members of families not typically represented in those spaces feeling confused and seeing them as irrelevant (Dawson, 2014; Garibay et al., 2017). On the contrary, when STEM learning is reconceptualized to reflect the cultures of a broader range of communities, informal spaces become accessible to racially, ethnically, linguistically, and economically diverse families (Garibay et al., 2017). Such findings lead to questions about how to design meaningful STEM learning environments in public spaces for families in minority positions of power in ways aligned with their cultural experiences.

1.2. Latine families' funds of knowledge

FoK refer to the "historically accumulated and culturally-developed bodies of knowledge" essential for individuals' and families' well-being (Moll et al., 1992, p. 133), countering deficit thinking of linguistically, economically, and culturally diverse students by underscoring families' assets in their community (Llopart & Esteban-Guitart, 2018). FoK include various concepts such as beliefs, values, practices, knowledge, skills, and experiences at home and in the community (Hogg, 2011). FoKs of Latine families include values like *familismo, educación* and practices like family food routines and oral communication which are also highly valued forms of cultural transmission (Evans et al., 2011; Reese, 2012). *Familismo* stresses family interconnectedness and reciprocity among family members (Calzada, 2010; Steidel & Contreras, 2003), while *educación* refers to connected moral, social, and academic goals for children to contribute to the family and broader community (Cycyk & Hammer, 2020; Halgunseth et al., 2006; Hernandez et al., 2016). Higher endorsement of those values related to warmer parent-child relationships, better emotional and peer adjustment, and greater approaches to learning skills (Denmark et al., 2014; Gamble & Modry-Mandell, 2008). Similarly, family food routines and oral practices provide comfortable cultural contexts that can enhance children's learning (Hammer & Sawyer, 2016; Leyva et al., 2021; Melzi et al., 2022).

Successful programs have leveraged Latine families' FoK to create meaningful learning across contexts. For example, food routines were used to bridge home-school literacies (Durá et al., 2015) and facilitate parent-child interactions with positive impacts in the "Food for Thought" program (Leyva et al., 2021). Similarly, wordless and culturally centered books reflecting Latine heritage promoted stories and questions at home and in the classroom, increasing children's narrative skills (Boyce et al., 2010; Hammer & Sawyer, 2016; Schick et al., 2021). A growing body of work exists around family values and practices for Latine families, but gaps remain as to how to build those assets into culturally situated guided play opportunities. Furthermore, the literature on FoK mostly focused on home-school connections (Llopart & Esteban-Guitart, 2018), overlooking home-community connections for children's learning. Partnering with community members ensures that STEM learning spaces reflect the interests, learning cultures, and knowledge of the communities they will serve (Bang & Medin, 2010; Penuel, 2017).

1.3. Community-based design research

We can utilize CBDR to create culturally situated STEM learning opportunities (Ahn et al., 2018; Bang & Medin, 2010; Belgrave et al., 2022; Tzou et al., 2019). CBDR involves multimethod or multiphase designs that follow core principles such as collaboration between stakeholders, an iterative research process, building trust and rapport with community members, and valuing multiple forms of knowledge (Leavy, 2017). This approach positions community members as design partners rather than recipients (Uchidiuno et al., 2017), legitimizing their FoK and disrupting traditional power dynamics (Nasir et al., 2008). As part of the PLL initiative, Belgrave and colleagues (2022) conducted sessions with Latine parents to learn about their family experiences grocery shopping and co-designed grocery store signs meant to engage families in STEM practices in their everyday routines. Thus, CBDR helps create STEM experiences grounded in the everyday contexts of local families, increasing their accessibility, usability, and sustainability (Fishman & Krajcik, 2003). More research-community partnerships are needed to make asset-based early STEM learning accessible to Latine families.

1.4. Current study

We aimed to create PLL in community settings reflecting the FoK of underserved immigrant Latine families to promote meaningful guided play and early STEM learning. We partnered with Latine families from a local community organization to (a) identify their cultural values and familial practices that could support STEM learning for young children and (b) co-design playful STEM learning opportunities in everyday spaces. We used CBDR to position Latine parents as (a) *informants* of their experiences through value mapping and storytelling activities and (b) *design partners* through design activities (Druin, 2002). The iterative nature of CBDR enabled us to move between eliciting families' FoK, prototyping, and soliciting community feedback to produce the designs. We asked:

1 What FoK – cultural values and practices – of Latine families can we leverage to engage children in culturally situated early STEM learning?
2 How do the designs reflect Latine families' FoK, playful learning principles, and early STEM practices?

This study addresses gaps in the literature related to Latine families' FoK in early childhood that support science, math, and playful learning at home and in the community. We also follow policy recommendations to make out-of-school STEM learning accessible to marginalized communities by leveraging everyday spaces and CBDR to create culturally situated opportunities aligned with research on children's learning (Hurst et al., 2019). Importantly, we provide a model for how to elicit and align families' FoK across settings and insights into values and practices we integrate in the design of learning experiences for Latine families.

2. Method

2.1. Design partners

We developed a partnership with the Santa Ana Early Learning Initiative (SAELI), which is formed of local families, teachers and administrators from the local school district, nonprofits, and public agencies. SAELI's mission is to increase enrichment opportunities for children 0 to 9 years old. Children in the local school district are predominantly Latine (80%), from low-income (87%), and from Spanish-speaking families (79%). Initially, an author and principal investigator of the study joined a SAELI meeting to share with its members about PLL previously created in other cities and the vision for Santa Ana. Then, in early October 2020, a director of SAELI sent emails and text messages to 62 parents involved in SAELI ($n = 59$ mothers, $n = 3$ fathers), inviting them to participate in the partnership. As a result, our design partners were 32 parents and the two program directors of SAELI who attended the virtual co-design sessions. Most parents immigrated to the United States from Mexico or were of Mexican heritage ($n = 29$), but a few immigrated from El Salvador, Guatemala, and Argentina ($n = 3$). One parent was a father, while all others were mothers, and almost all parents spoke primarily Spanish ($n = 31$).

2.2. The design process

Fig. 1 shows the multiple steps of our design process: (a) virtual co-design sessions, (b) virtual interviews, (c) data analysis, (d) use of data to inform the design of PLL, (e) in-person play test and feedback sessions, (f) iteration, and (g) updated designs. We held all sessions in Spanish to prioritize parents' language and analyzed the original Spanish transcripts of video and audio recordings for a more accurate interpretation of the data. We compensated parents $50 for each 2 hour co-design session and $25 for 1 hour interviews. The details for each step of the design process are provided below.

2.2.1. Virtual co-design sessions

We conducted seven 2 hour monthly virtual co-design sessions due to the COVID-19 pandemic. We had high participation rates with attendance per session ranging from 72% to 97% of parents and most parents (80%) attending at least six sessions despite the sessions being online. We facilitated co-design activities in small groups with four to seven parents each and had whole group discussions to ensure multiple avenues to gain community perspectives in line with CBDR principles. The small and whole group discussions were all video-taped for later analyses. Table 1 shows the date, goals, and activities for each session.

We used value mapping and storytelling to elicit families' values and practices in community spaces. For example, parents completed a "Madlib" activity to form community design principles for creating PLL (Clark et al., 2022), *"Me gustaría que creáramos algo _ (descriptivo) para promover _ (un valor), asegurándonos que las personas _ (característica) se sientan bienvenidas y _ (un sentimiento) mientras forman parte de los paisajes"/* "I would like for us to create something _ (descriptive) while upholding _ (a value), making sure people who are _ (a characteristic) feel welcomed and _ (a feeling) when being part of the PLL." Parents also shared pictures of spaces they liked to visit with their children, why they liked to visit, and the math and science learning that naturally occurs in those spaces (Le Dantec et al., 2009). Prompts to elicit storytelling included, *"Cuéntenos una historia sobre cuando haya ido de compras al supermercado con su familia cuando usted era niña(o) o con sus hijos"/* "Tell us a story about when you went grocery shopping with your family as a child or with your children."

Design-based techniques allowed our partners to ideate on the types of PLL they would like to see in their community and used arts and crafts, "Bags of Stuff," to build prototypes (Walsh et al., 2013). Our research team prepared bags with materials that would allow parents to make designs (e.g., construction paper, scissors, tape, pipe cleaners, etc.) and dropped them at a community center in Santa Ana known to SAELI members. Our design partners either picked up the bag from the center or accepted the director's offer to have it dropped off at their house. In the virtual sessions, parents created prototypes by merging characteristics from three sets of design principles (see Fig. 2), (1) community values that emerged from the value mapping activities, (2) playful learning principles (Hirsh-Pasek et al., 2020), and (3) STEM practices and crosscutting concepts from The Early Science Framework (an early childhood version of the Next Generation Science Standards; Greenfield et al., 2017). The design principles were visible when parents designed the PLL, and facilitators helped them brainstorm ideas as to how to merge play and STEM principles with their values and experiences. Parents also provided feedback on each other's designs, highlighting the

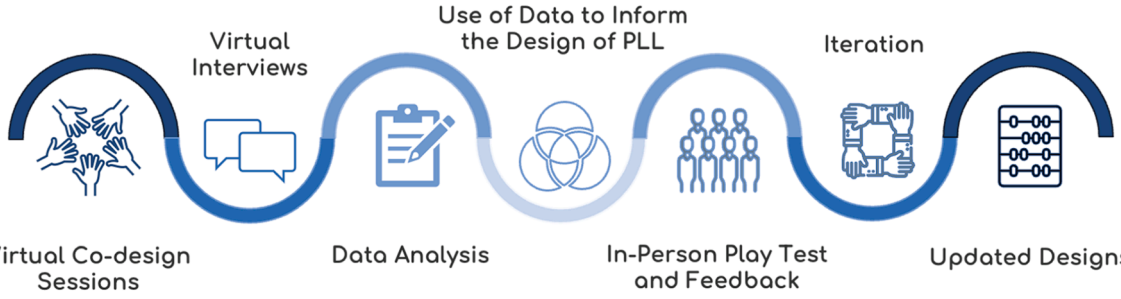

Fig. 1. The design process.

Note. This figure demonstrates the design process of the research-community partnership with the Santa Ana Early Learning Initiative (SAELI) community organization. The process began with seven virtual co-design sessions with Latine parents and program directors of SAELI. The co-design sessions consisted of value mapping, storytelling, and design activities to elicit their funds of knowledge and designs for playful learning landscapes (PLL). We then conducted one-on-one virtual interviews with a subset of 10 mothers to learn about their science, math, and play practices at home. We adopted a thematic analysis to identify themes and designs across participants and sessions. The research team then used the data to refine parents' designs of PLL, enhancing their alignment with our guiding design principles – families' values and practices, playful learning principles, and early STEM practices. Afterward, we had two in-person sessions with Latine parents and children for them to play with life-sized mockups of the elaborated designs and provide feedback. Finally, the research team iterated on the designs to incorporate families' input and create the updated designs of the PLL.

collaborative and iterative nature of the process.

2.2.2. Virtual interviews

One-on-one semi-structured 45–60 min virtual interviews were conducted with a subset of 10 mothers to gain a deeper insight into the assets of Latine families for STEM learning in home and community contexts. We interviewed only a portion of our design partners as this would give us sufficient complementary information about families' practices without the need to interview all our design partners ($n = 32$). The director of SAELI reached out to parents and provided our research team with the names and contact information of the first ten mothers who showed interest in being interviewed. We contacted the mothers via phone to give more details and schedule the interviews. In the interviews, we asked, "*¿Qué hace con sus hijos para divertirse?*"/ "What do you do with your children for fun?", "*¿En qué tipo de actividades usted y su familia participan en casa relacionadas al aprendizaje de las ciencias? ¿Y de las matemáticas?*"/ "What type of activities do you and your family engage in at home related to science learning? And math?" to learn about families' STEM learning at home that we could expand to the community.

2.2.3. Data analysis

Video recordings were transcribed from the co-design sessions and the interviews using transcription software and Spanish-speaking research assistants for verification. The transcribed data included 44 small breakout groups and 10 interviews. Native Spanish-speaking members of our team coded two sets of qualitative data to conduct an inductive thematic analysis across all the data sources.

Coding value mapping, storytelling, and interview data. The first set of qualitative data consisted of transcripts for the breakout groups focused on value mapping and storytelling ($n = 15$: 7.17 hours) and the interviews ($n = 10$: 9.67 hours). We used an inductive approach to create a codebook from the transcripts ($n = 25$, 16.83 hours). Three graduate students underwent four iterations of the codebook with 25% of the transcripts to create a final codebook reflecting families' experiences, values, and practices, and identifying subcodes for the social agent (child, parent, family, or people in the community) and setting involved (home or community). We coded all transcripts with the final codebook using Dedoose qualitative software. For member check-in, two coders coded 48% of the transcripts and regularly discussed alignment.

Coding design-based data. The second type of data were transcripts of the design-based breakout groups where parents brainstormed ideas, built designs of PLL, and iterated on those designs ($n = 29$; 31.17 h). Graduate and undergraduate research assistants reviewed the 29 transcripts from the design-based data. We extracted parents' descriptions of design ideas or prototypes, the interactions they designed for (e.g., games for math learning), the location they designed for (e.g., a bench), and connections between the designs and their experiences.

Inductive thematic analysis. We analyzed parents' excerpts and designs to identify consistent themes across participants and co-design activities. Four main themes emerged from the interactions between prominent primary codes with the sub-codes of family, home, and community (Table S1). We used the findings to inform the next phase of the design process.

2.2.4. Use of data to inform the design of PLL

Our research team for the 2020–2021 academic year ($n = 11$) used findings from the data analysis and the descriptions of parents' design ideas and prototypes to create refined designs aligned with the design principles in Fig. 2. First, three graduate students presented the findings to create a *shared understanding* of Latine families' FoK. The team then reviewed the parents' design ideas and prototypes to select a subset aligned with their FoK. We then used the "how might we" technique (Belgrave et al., 2022) to *enhance the alignment* of the PLL designs to multiple design principles- community values, playful learning principles, and early STEM practices and concepts. For example, if a design promoted family unity but not heritage, we asked, "How might we incorporate families' heritage?" and brainstormed ideas. Similarly, if a design fostered active engagement but not iteration, we asked, "How might we provide different ways for families to engage?" We did not aim to include all characteristics under the guiding principles, but rather to have refined designs with attributes from each category. Finally, we worked with designers to *create visual graphics* of the elaborated designs.

2.2.5. In-person play test and feedback sessions

The SAELI director invited our design partners ($n = 32$) and their families to participate in the in-person playtest and feedback sessions. As a result, we conducted two 2 hour in-person playtest and feedback sessions with 23 of our design partners and their children ($n = 44$) aged 5- to 16-years-old (45% female) who could attend. Of the children, 34% ($n = 15$) were between 5 and 8 years old. In the sessions, families played with life-sized mockups of the installations and gave feedback. We expanded children's ages beyond early childhood due to parents' desire to also engage older siblings. During the sessions, family units rotated between PLL for three community spaces – bus stops, parks, and murals. We asked families to imagine themselves at those sites as they explored and played. At each site, families spent 20–30 min playing and 15 min providing verbal or written feedback. We asked for overall input, "*¿Qué le gusto o que no le gusto?*"/ "What did you like or didn't like?" and targeted feedback, "*¿Qué les gustaría hacer como familia con estas tarjetas*

Table 1
Overview of the virtual co-design sessions.

Session Date, Goals, and Activities
(1) ***October 2020 –*** To create a mutual understanding of the partnership, learn about families' experiences and STEM learning in community spaces, be transparent about selecting sites, and build trust and community. *Activities:* (a) Presentation led by the research team on previous examples of PLL and co-design partnerships. (b) Storytelling activity of the community spaces families visit, the math and science learning that occurs there, and the social relationships sustained in those spaces. (c) Presentation led by the program directors of SAELI to explain the selection process of sites and to address parents' questions and concerns.
(2) ***November 2020 –*** To answer the question, "What are our community values?" *Activities:* (a) Storytelling using parents' photos of community spaces to learn about how families engaged in those spaces, why parents valued those spaces, the characteristics of people there, and the feelings they had in those spaces. (b) Value-mapping using a fill-in-the-blank activity to learn about the values, characteristics, and feelings parents wanted to see reflected and evoked during their time at PLL. (c) Value-mapping activity of the essential criteria we should consider in selecting community sites.
(3) ***December 2021*** – To learn about our guiding design principles, families' everyday science learning, and get parents to begin to design PLL for community spaces. *Activities:* (a) Presentation led by the research team on the community values from previous co-design sessions, principles of playful learning, and practices and concepts from the Early Science Framework. (b) Storytelling on the everyday science things parents do as a family. (c) Design activity with arts and crafts for parents to design PLL using the community values, playful learning principles, early STEM practices and concepts, and community spaces as design principles. (d) Fun work for parents to iterate on the designs with their children.
(4) ***January 2022*** – To iterate on parents' design ideas for a bus stop and review the design principles. *Activities:* (a) Storytelling of parents' experiences iterating with their children. (b) Presentation reviewing our guiding design principles – community values, playful learning, and early STEM practices and concepts – and the partnerships' timeline. (c) Design activity for iterating on bus stop designs focused on parents providing feedback on what they liked, what could be improved, and extensions to the designs.
(5) ***February 2022*** – To revisit our understanding of the mutual goals of our partnership, experience a previous PLL, and learn about parents' experiences playing. *Activities:* (a) Presentation and discussion led by the program directors of SAELI about how our partnership fits within the organization's overall goals. (b) Play activity where parents played an adapted version of a life-sized board. (c) Design activity where parents provided feedback on how the game could be improved.
(6) ***March 2022*** – To learn about families' experiences grocery shopping, get parents' feedback on grocery store signs from another PLL project, and have parents design their grocery store signs. *Activities:* (a) Storytelling activity of parents' experiences grocery shopping with their family as children and parents. (b) Play activity where parents utilized grocery store signs in their kitchen to engage with their children in STEM learning and provided feedback on their experiences and the designs. (c) Design activity where parents created new signs that would promote math and science learning while reflecting their community values.
(7) ***May 2022*** – To engage parents in the design of PLL, share the next steps for the partnership, and hear from parents regarding their experiences in the co-design sessions. *Activities:* (a) Presentation on several community spaces and parents' nominations of the top spaces they would like to design for. (b) Storytelling of parents' experiences in the space they are designing for. (c) Design activity using arts and crafts to create PLL, including a learning goal and cultural values they found most important to emphasize. (d) Presentation on the next steps and reflection on the process and partnership.

mientras esperan el autobús?"/ "What would you like to do as a family with these cards while waiting for the bus?" We audio-recorded families' responses and gathered their notes to refine the designs.

2.2.6. Iteration and updated designs

Three research team members reviewed transcripts from the audio recordings (n = 16: 3 hours) and the short answers (n = 240) to synthesize the main themes from families' feedback. The researchers worked independently and then met as a team for triangulation. Next, the full research team for the 2021–2022 academic year (n = 12) engaged in weekly meetings to iterate on designs, incorporating feedback from families and enhancing alignment with the design principles. Fig. 3 shows an example of the progression from parents' design ideas during the co-design sessions to the final prototype.

3. Findings

3.1. Funds of knowledge of Latine families to leverage in early STEM learning

The analyses led to three themes: (1) parents highly valued *familismo* for children's development and learning across contexts, (2) parents desired to see their heritage reflected in learning opportunities in meaningful community spaces, and (3) families' STEM practices were rooted in everyday contexts – cultural games, family food routines, and outdoor activities – and influenced by their cultural values. Fig. 4 shows a conceptual map of Latine parents' values and family practices in out of school settings and their relation to culturally situated PLL.

3.1.1. Familismo: central for children's development and learning across contexts

Our Latine design partners emphasized collaboration, family unity, and intergenerational learning amongst family members as crucial for their families, echoing the concept of *familismo* that encompasses reciprocity and strong ties between family members and shared daily activities (e.g., Calzada 2010). Our design partners appreciated children's support and family members collaborating on tasks across a variety of contexts at home and in the community:

> *Pues muy orgullosa de mis hijos, de la familia que tengo, porque tanto ellos me apoyan a mí como yo a ellos; mientras estoy con las más pequeñas ayudándoles con la tarea, las mayores me ayudan a limpiar la casa, hacer de comer o cualquier otro quehacer*. I am very proud of my children, of the family that I have because they support me as much as I support them; while I am with the young ones helping them with homework, the oldest ones are helping me clean the house, cook, or with any other chore.

> *Tengo seis niños y todos quieren ir a estar ayudando [mientras compramos el mandado] y mando uno a agarrar limones, el otro agarrar diez tomates, entonces se nos hace fácil porque entre todos acabamos rápido*. I have six kids, and they all want to help [during grocery shopping], so I send one to get lemons, another one to get ten tomatoes, so it becomes easy because with everyone helping, we finish quickly.

Parents found it gratifying and valuable for children to contribute to family activities that served the goals of the family unit within everyday contexts like household chores and grocery shopping. The importance of collaboration amongst family members expanded from families' lived experiences to the designs they created and envisioned for their family interactions and children's learning in community spaces: *"Estoy hablando de lo que es la ciencia, las matemáticas, las figuras. Dije la cultura porque el árbol con las raíces me gustó por la forma de la familia y como todos debemos que participar para crear algo más grande."* "I am talking about science, math, and shapes. I said culture because I liked the tree with the roots due to the family structure and how we all must participate to create something bigger."

Family unity was another prominent expression of *familismo* that led parents to desire intergenerational learning opportunities for their family in the type of interactions parents wished for PLL to foster. For example, when given the "Madlib" prompt described earlier, parents

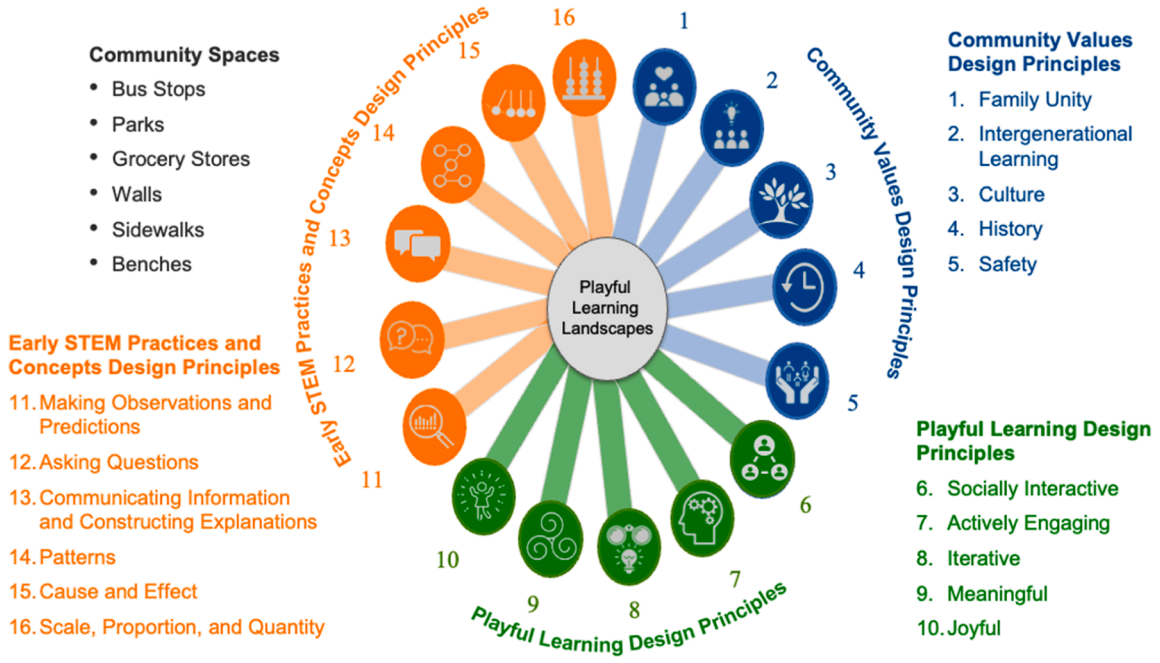

Fig. 2. Design principles for playful learning landscapes in community spaces for our partnership with Latine families from Santa Ana.
Note. The guiding design principles used by (a) our Latine design partners in creating playful learning landscapes for community spaces during the virtual co-design sessions and (b) the research team in the elaboration and iteration steps of the design process.

Fig. 3. Example of the design process.
Note. The figure shows the progress from a parents' original design prototype to the iterated design for what became the *Lotería* game for a bus stop. (A) During a virtual co-design session, a mother shared her design idea for utilizing a spinning wheel for children to learn math concepts. (B) The mother then iterated on the prototype with her children, changing each wedge to facilitate different STEM concepts (e.g., comparing flags of countries, categories of animals, and shapes). After the data analysis, (C) the research team elaborated on the design to combine *la Lotería*, a prominent normative practice, into the spinning wheel for families to turn cards and complete prompts in the back of the cards related to STEM learning and created a graphic design of the updated design. (D) Families then play-tested with life-sized mockups of the refined designs and (E) provided verbal and written feedback of their experiences and suggestions. (F) We iterated on the designs, incorporating the families' input, to create the updated designs.

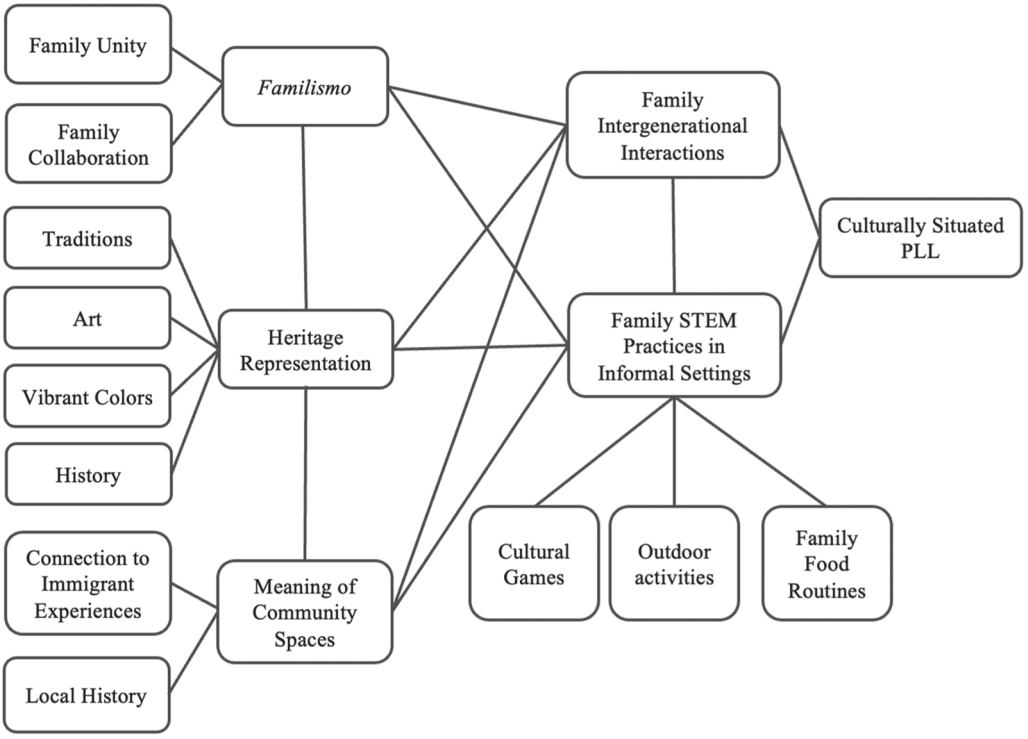

Fig. 4. Conceptual map of Latine parents' values and family STEM practices in informal settings.

said they would like to create something *"divertido"* (fun) to promote *"el aprendizaje y la unión familiar"* (learning and family union), while making sure people who are *"de todas las edades"* (of all ages) feel welcomed and *"seguros"* (safe) while being part of the playful landscapes.

Other parents responded with similar words to the value-mapping activity, *"como familia,"* "as a family," *"la unión familiar,"* "family union," *"unidos,"* "united," and *"interactuar en familia"* "family interactions," to indicate strong family bonds as essential to foster through the PLL. The values of family unity and collaboration within the family motivated parents' desire for intergenerational learning, such that people *"de todas las edades"* "of all ages" and *"niños, jóvenes, adultos, y abuelos"* "children, teenagers, adults, and grandparents" can play and learn together. Thus, collaboration, family unity, and intergenerational learning were critical facets of *familismo* parents valued for children's learning across contexts.

3.1.2. Heritage: cultural transmission and children's learning in community spaces

Parents yearned to see their heritage- culture and history- reflected in environments meaningful for local families in community spaces. Parents often mentioned the desire for children to learn STEM content while also learning about parents' cultural traditions and the culture and history of their native countries. References to heritage included traditional regional clothing, historical figures (e.g., artists, poets, national heroes), and flags from different countries. Such descriptions were prevalent in parents' design ideas, emphasizing the importance of having families feel that their culture is represented and honored. A parent shared, *"estaría muy bonito que pusieran historias de varios países, historias de nuestros ancestros… Historias de héroes que han hecho un cambio."* "It would be beautiful if you put stories from various countries, stories from our ancestors… Stories of heroes that have made a change." Similarly, another parent suggested, *"un mural con la sombra de una persona, y en cada parte del cuerpo tiene las banderas de diferentes países. Pueden dar el total de cuantas banderas forman el cuerpo."* "A mural with the shadow of a person, and each part of the body is composed of flags from different countries. They can give the total of how many flags form the body."

It was evident parents wanted their *"hijos nacidos aquí [en los Estados Unidos] que aprendan de eso,"* "children born here [the United States] to learn about it" – historical figures in their native country and cultural traditions – while engaging in STEM learning. Parents viewed representative images of their heritage as opportunities to engage in meaningful storytelling and learn about similarities and differences across cultures while aiding scientific and mathematical thinking. Other critical cultural elements stressed by parents were art and bright colors because they were emblematic of Latine culture, *"los colores estaría bien porque aparte del arte, tú aprendes de tu cultura,"* "the colors would be good because in addition to art, you learn about your culture." Colorful designs that incorporate art were viewed as more effective for engaging families with the PLL because they would be more visually appealing to children and adults.

While parents placed high value on transmitting the heritage of their native country to their children, they also frequently spoke about important experiences and ties to their local community spaces. Parks were particularly seen as spaces that are meaningful to families, linked to their history in the United States, and essential for family unity and learning. Some of the mothers spoke about the involvement of parents in their community and the value of unity in fighting for public spaces for their families, *"en la comunidad nosotros luchamos mucho por este parque, diez años de lucha… Y el valor más importante es la unión. Se llama Mariposa Park, que representa a los inmigrantes como yo y muchas de mis compañeras que están aquí."* "In the community, we fought a lot for this park, ten years of fighting… And the most important value is unity. Its name is Mariposa [Butterfly] Park, representing immigrants like myself and many of my peers here." Parks were also viewed as a space for family reunions, imitating the affordances given by other community spaces in their native country:

> *Es algo que uno añora porque en nuestros países íbamos al kiosco o a la plaza, porque son reuniones en familia. Es lo mismo cuando vamos a los parques. Es algo muy bonito, que tomen en cuenta los parques. Es la unión familiar que es un valor muy importante.* It is something that we yearn for because, in our countries, we would go to the kiosk or plaza

because they are family gatherings. It's the same thing when we go to the park. It's beautiful that you consider parks. It is family unity, which is a very important value.

Given the importance of local spaces, parents' design ideas for STEM learning often leveraged the layout of their community. For example, several design ideas included mapping for families to see bus routes, streets, children's places in Santa Ana, and familiar buildings that could help young children learn about distances and spatial relations (e.g., left, right, up, down). These examples highlight the importance of identifying meaningful community spaces for families and leveraging their connection to those spaces for children's STEM learning.

3.1.3. Family STEM practices rooted in everyday contexts

Latine families' practices supporting STEM learning were rooted in everyday contexts in home and community settings. Playing cultural games, engaging in food routines, and doing activities outdoors were predominant ways families engaged in STEM learning, reflecting values of *familismo* and heritage. Playing cultural games facilitated positive family interactions while promoting children's math learning, a practice rooted in parents' cultural traditions growing up in another country: *"Juegos de mesa que yo jugaba con mis papás y hermanas… Les explicaba [a sus hijos] cómo se jugaba… Y hay un juego que me fascinó desde niña, el de Basta. Y me gusta porque ahí va uno aprendiendo."* "Board games that I played with my parents and sisters… I would explain [to her children] how to play them… There's a game that has fascinated me since I was little, *Basta*. I like it because we are learning." Family practices informed parents' ideas for PLL, *"La Lotería. Tener imágenes que los niños reconozcan sería bonito… Un juego de memoria o patrones. Dos tarjetas de la mano y luego la bota, ¿qué sigue? Me gustaría que este juego reflejará la comunidad de Santa Ana."* "*La Lotería.* Having images children recognize would be nice… a memory or patterns game. Two cards showing a hand and then a boot, what comes next? I would like for this game to reflect the Santa Ana community."

Family food routines – cooking and grocery shopping – were other prominent ways parents supported children's math and science learning in natural ways. For example, parents spoke about children helping plan meals and making predictions about food quantities they would need for cooking. Furthermore, cooking was a joyful family activity that engaged children in counting food items, measuring, comparing food quantities, and learning about shapes: *"Cocinamos paletitas de pastel. Me gusta porque ellos participan... Es muy bonito compartir con ellos. Y les enseñamos a contar. Les digo, 'lean en la caja cuánto se necesita y que le vamos a poner.'"* "We cook cake pops. I like it because they participate… It's beautiful sharing with them. And we teach them to count. I tell them, 'Read in the box how much is needed and what we are going to put on it.'"

Similarly, when discussing their family grocery shopping experiences, parents shared examples of engaging children in mathematical thinking by having them weigh food items, compare prices, add costs, and determine if the total was within their budget. Furthermore, children engaged in scientific thinking by observing the qualities of fruits to decide whether they were ready to be eaten or needed more time. Those interactions supported children's mathematical and scientific learning while providing joyful family interactions during cultural family practices: *"Cuando voy con mis niños les gusta ayudarme. Por ejemplo, les digo cómo agarrar los jitomates, que no estén verdes pero que estén poquito duritos para que nos alcancen para la semana"* "When I go with my children, they like to help me. For example, I tell them how to choose tomatoes that are not green but are a bit firm so they will last over the week."

Finally, parents engaged with children in everyday science and math learning in outdoor settings. For example, they walked, jumped, or ran to count and measure time and distance, *"salir a caminar y cada brinco que dábamos lo contábamos… pusimos una meta de cuánto [tiempo] teníamos para dar la vuelta y contábamos los minutos."* Go out for a walk and we counted every jump we did… we had a goal of how much [time] we had to go around, and we would count the minutes." They also used "I spy" types of games to make observations around their surroundings to identify and count objects from a specific category, *"los ponemos a contar cuantos carros había de diferentes tipos de colores… era lo que hacíamos, los colores, cuantos carros, y que tipo de carros eran."* "We ask them to count how many cars there were of different colors… that's what we did, the colors, how many cars, and what types of cars they were." These examples highlight the math and science practices Latine families engaged in during everyday activities. Together, these findings demonstrate the broad range of funds of knowledge of Latine families that we can leverage in the design of PLL.

3.2. Designs reflect Latine families' FoK, playful learning, and early STEM practices

We designed and tested seven PLL installations using the design process outlined above. Fig. 5 shows examples of the designs we created. The designs resulted from an iterative process with our community partners, aligning families' funds of knowledge with play and early STEM learning principles (see Fig. 2) during co-design sessions with parents, elaboration by the research team, and iteration based on families' feedback. In this section, we use *Lotería* Bus Stop as an example to demonstrate how this process can lead to culturally situated PLL merging the values and practices of Latine families with play and early STEM learning principles.

La Lotería is a popular traditional game (like Bingo) played by many families in Mexico and the United States (Stavans, 2003). In *Lotería* Bus Stop, there are 8 boards of 9 traditional *Lotería* cards and families see the prompt, *"¡Gira, voltea, y responde!* Spin, flip, and answer!" Families are prompted to spin the wheel, turn the card on their board, and complete the prompt in the back, focused on families' STEM practices aligned with the Early Science Framework. Some boards have challenging prompts in response to families' suggestions to engage older siblings.

3.2.1. Alignment with the design principles

Lotería Bus Stop leverages parents' values of family unity and their desire for PLL that promote intergenerational learning and reflect their culture. The design provides a comfortable context for many family members to engage given the popularity of *la Lotería*, fostering family unity and intergenerational learning. Furthermore, it aligns with parents' desire to see their culture represented in local spaces, as *la Lotería* is representative of Mexican households and the images show the vibrant colors that appeal to families. Several parents mentioned playing the traditional game with their families, and games were a prominent way families played and spent time together, further reflecting family unity. Finally, *Lotería* Bus Stop came from merging multiple elements from different parents (e.g., a spinning wheel to play and learn math and science concepts, using *la lotería* images in a memory or pattern game).

The design also aligns well with principles of play promoting content knowledge and domain-general skills. Specifically, it supports *active engagement*, given that family members need to spin the wheel, turn cards, and complete prompts, which also encourage physical activity by counting jumps or squats. The design also promotes *joyful* interactions as families enjoy spinning the wheel and answering prompts embedded within the game. In addition, families are more likely to find this installation *meaningful* because it reflects their heritage and practices. *Lotería* also promotes *social interaction* because family members can play and interact (e.g., *"Pregúntale a tus padres que saben de su animal favorito"*/ "Ask your parents what they know about their favorite animal"). Finally, prompts ask families to make observations, resulting in *iterative* environments (e.g., *"¿Cuantos carros están a tu derecha? ¿A tu izquierda? ¿Cuál lado tiene más?"*/ "How many cars are to your right? To your left? Which side has more?").

We wrote prompts to align with practices and crosscutting concepts from the Early Science Framework and families' practices. The prompts ask children and families to engage in the scientific practices of observation and making predictions (e.g., *"¿Cuantos pasos crees que sea igual*

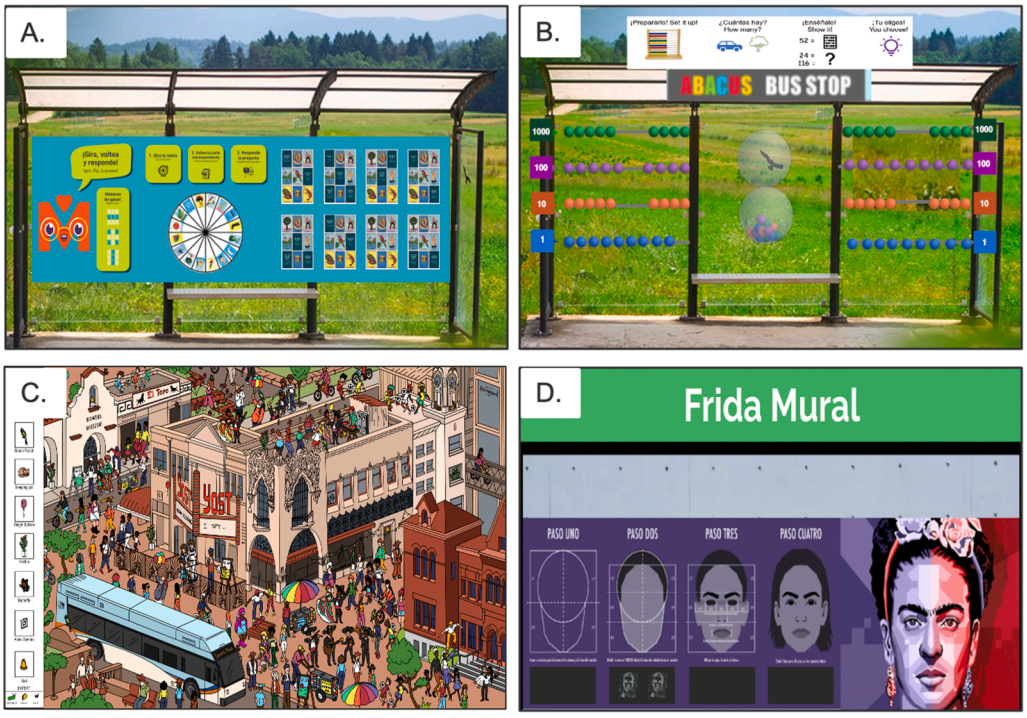

Fig. 5. Examples of the designs for community spaces.
Note. The figure shows examples of the designs for the installations that came to be known as *Lotería* Bus Stop (A), Abacus Bus Stop (B), I Spy Mural (C), and Frida Mural (D). The designs originated from parents' design ideas or prototypes during the co-design sessions and were elaborated on by the research team to further align with community values (e.g., family unity, culture, history, intergenerational learning), playful learning principles (e.g., socially interactive, actively engaging, iterative, meaningful, joyful), and early STEM practices and concepts (e.g., making observations and predictions, asking questions, patterns, scale, proportion, and quantity).

de largo que este banco? Cuenta los pasos. ¿Qué tan cerca estuviste?"/ "How many steps long do you think this bench is? Count the steps. How close were you?"), math and computational thinking (e.g., *"¿Cuantos carros pasan en un minuto?"*/ "How many cars pass by in one minute?"), and communicating information and constructing explanations (e.g., a picture of a fish swimming, *"¿Qué tiene este pescado que le ayuda a vivir en el océano?"*/ "What about this fish helps it to live in the ocean?"). The prompts also ask families to engage in the cross-cutting concept of patterns (e.g., repeat patterns of animal sounds). *Lotería* Bus Stop illustrates how research-community partnerships can lead to culturally grounded learning environments that align families' funds of knowledge with play and STEM learning principles.

4. Discussion

This study bolsters our understanding of Latine families' funds of knowledge – values and practices – related to play and STEM learning in the home and community spaces. It also responds to the policy call to create early STEM learning opportunities that are more accessible to marginalized and under-resourced communities by creating learning environments in the everyday spaces families naturally visit and adopting CBDR to increase their cultural relevance (Hurst et al., 2019). Our findings showed that Latine families have a broad range of cultural assets that support children's play and early STEM learning, and we can leverage them to strengthen home-community connections in designing learning environments for families.

Familismo, representation of heritage, and the meaning of community spaces influenced how families interacted and the learning opportunities Latine parents desired in community spaces to engage all family members in playful STEM learning. While previous research has investigated *familismo* and cultural representation on students' STEM outcomes mostly in higher education (e.g., López et al. 2019, Rodriguez et al. 2021), our findings show they also have an essential role in early childhood. Thus, parental *familismo* attitudes in early childhood are important influences not only in social behaviors and childcare decision making (Stein et al., 2014), but also in the context of STEM learning. Similarly, studies with Latine populations investigating community spaces like parks have focused primarily on contexts like health outcomes (e.g., Lindsay et al. 2009, Marquet et al. 2019), and few studies have investigated what influences Latine families to play outdoors (Grzywacz et al., 2016). We contribute to the literature by showing the history of local spaces and opportunities to spend family time and learn about their culture influence Latine families' decisions to visit community spaces and engage in outdoor play, which is conducive to STEM learning.

Our findings also highlight Latine families' STEM learning practices were embedded in everyday routines and contexts: playing board games and cultural games at home, engaging in family food routines, and outdoor activities in community spaces. These practices were rooted in parents' cultural practices growing up and reflected parents' emphasis on the values of *familismo* and heritage. Latine family food routines have been researched in the contexts of early STEM learning (Leyva et al., 2018, 2021), but we know less about how family games and outdoor play support early STEM learning in young Latine children, highlighting future areas of research.

Leveraging families' funds of knowledge and adopting CBDR can produce relevant learning environments that build from families' cultural assets and align with developmental and learning sciences research to better support children's learning. Thus, through this work we demonstrate a process for engaging Latine families in designing meaningful and evidence-based learning environments for young children that researchers and practitioners can adopt across other content domains, which has important implications for the accessibility, usability, and sustainability of those environments (Fishman & Krajcik, 2003). Furthermore, we contribute to the knowledge of Latine families' funds of knowledge in play, science, and math learning in the home and community settings that might extend to other areas.

5. Limitations and future directions

A limitation of the study is that the funds of knowledge and designs reported are almost exclusively from mothers' perspectives because of the context of our study and the recruitment strategy utilized. This study was conducted as part of a research-practice partnership with SAELI, where we invited parent members to participate in the co-design sessions. Only a few active members of SAELI are fathers. Thus, our

recruitment strategy limited the participation of fathers. However, we recognize the need to learn from fathers' perspectives in future designs of PLL as previous research suggests that Latine mothers and fathers can socialize their children differently, and children also respond to parents' practices differently depending on whether it involves mothers or fathers (e.g., Kuhns & Cabrera, 2020). In more recent co-design sessions related to this project that focuses on creating a playful STEM learning technology application that complements the physical PLL, we have made an explicit effort to recruit fathers, increasing their participation. A second limitation is that our design partners are highly invested in children's early education, as reflected in their SAELI membership and participation in this study, so their values and practices might not generalize to all Latine families and children from different age groups. Nonetheless, we aimed to understand multiple ways low-income Latine families can engage in STEM learning that can resonate with other families from similar backgrounds rather than privileging dominant practices. Finally, we have not yet assessed the impacts of the installations on children's learning and family dynamics, so we cannot judge the effectiveness of the designs in promoting culturally situated STEM learning, this is an important future direction and a next step in this work.

6. Conclusion

Understanding the values of families and how they manifest in everyday family interactions is essential to design spaces that are welcoming rather than alienating to families traditionally marginalized from STEM learning spaces (Garibay, 2009; Stein et al., 2008). Latine families have various cultural assets that support children's early STEM learning that we can leverage in designing learning environments. Our findings showed that *familismo*, heritage representation, and the meaning of community spaces play essential roles in Latine families' play and STEM experiences across contexts. We also found that everyday activities were common ways Latine families interacted and engaged in STEM, including cultural board games, family food routines, and outdoor activities. Although family food routines have been leveraged for children's early STEM learning (e.g., Leyva et al. 2018, 2021), our findings show that playing board games and outdoor settings are also prevalent and important contexts for Latine families even though they have been understudied in early childhood. Furthermore, creating environments in community spaces that echo local families' cultural values and practices are necessary to make them usable for families from marginalized communities. Adopting strength-based cultural theoretical models and partnering with community members are effective ways to investigate cultural schemas and early STEM socialization practices and design learning environments that connect families' experiences across contexts.

CRediT authorship contribution statement

Vanessa N. Bermudez: Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization, Project administration. **Julie Salazar:** Methodology, Formal analysis, Investigation, Project administration. **Leiny Garcia:** Methodology, Formal analysis, Investigation, Data curation, Writing – review & editing, Project administration. **Karlena D. Ochoa:** Methodology, Investigation, Writing – review & editing, Supervision, Project administration. **Annelise Pesch:** Methodology, Investigation, Writing – review & editing. **Wendy Roldan:** Methodology, Formal analysis, Investigation, Data curation, Writing – review & editing. **Stephanie Soto-Lara:** Investigation, Writing – review & editing, Project administration. **Wendy Gomez:** Investigation, Project administration. **Rigoberto Rodriguez:** Conceptualization, Investigation, Funding acquisition. **Kathy Hirsh-Pasek:** Conceptualization, Methodology, Investigation, Resources, Writing – review & editing, Supervision, Funding acquisition. **June Ahn:** Conceptualization, Methodology, Investigation, Resources, Supervision, Funding acquisition. **Andres S. Bustamante:** Conceptualization, Methodology, Investigation, Resources, Writing – original draft, Supervision, Funding acquisition.

Declaration of Competing Interest

We have no conflicts of interest to disclose.

Data availability

Data will be made available on request.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ecresq.2023.06.003.

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