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”Alright, Let’s Do This!”: An Exploration of Role-Taking Amongst Families in Informal Learning Environments (Fundamental)

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Abstract

This fundamental research paper focuses on improving our understanding of how families work to solve real-world problems. While some families may have members with engineering and design backgrounds who can articulate how to solve problems, others rely on their own intuition, knowledge, and personal experiences to help steer their child(ren) toward a solution. Often, these ill-structured problems require family members to adopt specific roles throughout the process to achieve their goal. In this study, we explore the role-taking behavior of parents and children as they complete a design challenge under time constraints and with limited low-tech materials. In particular, this work investigates how family members (parents and children) shift between roles as they progress through design stages, using a chronological mapping of transcribed video and audio recordings. The results suggest that family members' changing roles fell into 6 emergent categories, indicating nuanced shifts within the family and shedding light on similar trends across the data set.

Introduction

Collaborative problem-solving is a critical skill across the engineering profession. Families are impactful drivers of engineering engagement. How might family members adopt and transition between engineering roles in a team-based, informal design task? Family teamwork experiences provide unique opportunities to observe naturalistic problem-solving scenarios within which family members might demonstrate notable role-taking behaviors. Exploring family dynamics under design constraints can provide insight into how these cultural experiences inform children's engineering behaviors and mindsets, especially those with engineering interests.

Family Collaboration in Education/Engineering

This informal learning research paper focuses on better understanding how families work together on design projects. While we know that families each have their own cadence for working together, and even parents have their own parenting style, this work seeks to explore how they use their practices and how they emerge throughout the design process. Research shows the great impact of family engagement on academic achievement, sense of belonging, motivations, and interest in continuing along STEM pathways (Dou, 2019). Prior research suggests that families are essential partners in their children's learning (Murphy, 2020). This can inform disciplinary STEM practices such as teamwork, problem-solving, and decision-making (Allen and Noam, 2025). Family roles determine who gets to play with the video games next, who takes out the trash, and who decides which museum the family is going to on the next day trip. Role-taking in these activities indicates how a family makes decisions and may have implications for the development of children's problem-solving and behavioral skills.

Family teams offer authentic opportunities to understand how an engineering mindset is developed. Informal family activities can enable adult guardians and children to exercise engineering thinking and engineering skills. Family and home experiences can contribute to children's STEM skills, interest, and identity formation (Dou, 2019; Morris et al., 2021; Verdin, 2021; Vedder-Weiss, 2018).

For girls and families of color, members can make a huge impact in the field of engineering. The ways they support or hinder engineering their children's interests can have implications for the field itself. In fact, in a previous study of African American families, Tolbert Smith et al. (2022) found that Black parents support the use of specific tools, resources, and practices. Erol et al. (2025) identified ways in which families' involvement impacted girls' habit of mind, including systems thinking, creativity, collaboration, optimism, communication, and ethical responsibility.

Role-Taking and Social Roles in Teamwork

Increasingly, scholars are focusing their research efforts on family engagement in STEM informal learning. Contributions to this work indicate that parent-child STEM engagement produces outcomes related to problem-solving abilities, interest in engineering, identity and sense of belonging, and foundational STEM knowledge. Specifically, family conversations about STEM topics are influential experiences that shape STEM identity and career interest (Cian et al., 2022; Craig et al., 2018; Dou et al., 2019; Dou & Cian, 2021).

Previous research has identified the various roles that parents and caregivers/guardians embody and how these roles can support or hinder a child's career aspirations. More specifically, parents and caregivers can also influence how a child chooses to engage or disengage in the engineering design process. Simpson et al. (2023) investigation of adult-child dyads revealed the influence of explicit recognition and positioning on engineering identity. Role-taking is essential in these family engineering experiences and is a natural practice in teamwork. It is certainly an observable behavior with classroom and STEM identity development implications.

Understanding role-taking practices is critical to understanding how children develop and maintain an interest in engineering. Scholars contributed insights into the social and functional roles people adopt as they work on STEM projects. Roles such as teachers, collaborators, and co-learners informed the codebook for this project (see Appendix A). There are supportive roles, such as the Equity Advocate, who ensure that all participants have access to materials and opportunities to engage (Vossoughi et al., 2018, p. 8). A functional role such as the Supply Finder (Resource Finder) – Identifies and gathers materials needed for building and testing prototypes. (Bevan et al., 2015, p. 16). In the engineering design context, some roles blur functional social lines, such as the Spark Starter, who is considered a Curiosity Catalyst and who sparks children's interest in STEM by asking thought-provoking questions or telling them to try something new or challenging (Milner-Bolotin & Marotto, 2018, p. 10).

Sequential & Chronological Mapping

Timelines have long been used in design research as a technique for observing design process behaviors and activities as they occur in the moment and for identifying broader trends across the data. They are useful for visualizing sequences, trends, and transitions across the design process/experiences. They also allow for comparisons across participant types. This mapping technique has been used to explore novice and expert design cycles in classrooms to teach the design process and as a reflective tool for one's own design process. In research applications, it is often coupled with transcripts to identify segments based on utterances, enabling fine-grained analysis of engineering design thinking, behaviors, and activities.

Theoretical Framework

Theoretically, this work draws on situated learning and community of practice lenses, which emphasize interactive, dynamic participation (Lave & Wegener, 1991). They argue that learning occurs through co-participation with others. Learning is situated in a community with a shared domain of interest, context, experiences, and practices. This study uses this theory to understand how parents' and children's participation is shaped by roles and interaction throughout the design challenge. Role-taking from a community of practice perspective should be a dynamic interaction among family members to solve the problem within a given time frame.

In our analysis, we explore social practice by coding utterances into roles and using chronological mapping to identify and investigate shifts. These shifts act as enactments of the theory. Chronological mapping then becomes a tool for visualizing how situated learning and doing occur for each family in the study.

We interpret the result and explore role interactions and transitions to understand how engineering learning and doing occur across different families and within the data. We make sense of how transition types, which are unique to specific family units, give rise not only to family identity but may also shape a child's engineering identity.

Although knowledge about parent-child conversations in informal STEM settings is deepening, prior work leaves room to investigate family talk and sequences of role-taking and changing within families in engineering design settings.

Research Questions:

This present study investigates:

- How do family members negotiate and shift social and functional roles as they collaboratively engage in an informal engineering design challenge?
- What patterns of role emergence and change are revealed through chronological mapping of family interactions during the design process?

- How are the deductive codes enacted by family members converged, and what does this reveal about the nature of collaborative engagement in the design task?

Based on these theoretical and empirical foundations, we undertook a chronological mapping of family exchanges during an out-of-school design task to explore role-taking and role-changing practices.

Methodology

In this paper, we studied seven families who participated in the Amazon Drone Delivery Challenge, an adaptation of the Shawn Springs Lab Inventing History Program that the team previously facilitated. In this lab, families learned scientific principles behind concussion prevention technology developed by former NFL player and inventor Shawn Springs and applied them to a new context. They were tasked with designing and building a prototype carrier that could attach to a drone and protect fragile materials during delivery. Families were given approximately 60 to 75 minutes to complete the challenge using low-tech materials in an informal setting. The challenge required families to identify the problem, brainstorm and select solutions, plan and build a prototype, and communicate their design. A brief introduction and explanation of the design stages were provided at the beginning of the session to provide context; there was no in-depth instruction about the engineering design process. Families were not required to explicitly follow the design stages to complete the task. This approach allowed families to engage in the design process using their own intuitive problem-solving strategies, consistent with the program's informal learning goals.

A codebook of 29 distinct roles was generated from related literature, and transcripts were coded for conversational turns. The 27 codes ("social and functional roles") that applied to this data were then systematically reduced to six categories (Translators, Champions, Collaborators, Doers, Thinkers, and Leaders) for analysis.

Design Activity and Participants

In this context, this constraint-based family design activity took place during after-school STEM nights. The data includes video and audio recordings of each family. In this study, all families identify as Black or African American.

Analysis

Analysis was conducted using a combination of manual coding in Excel and computational tools in Python/pandas via Google Colab. The use of Python and pandas enabled greater efficiency, reproducibility, and flexibility in handling time-sequenced, categorical transcript data. IRB approval was granted through the University, and families gave informed consent.

Data Preparation and Coding

One team member was responsible for data preparation and for leading coding efforts. First, select a subset of data from the larger study. Each recording was reviewed and compared with the transcripts to ensure the accuracy of exchanges, segment IDs, and speaker assignments. Then the transcripts were segmented into excerpts and labeled by family, speaker, design stage, and speaker gender. Before analysis, author 2 read the full transcripts to understand the context and to familiarize herself with the interactions between family members. As she reviewed the transcripts, she documented her observations.

To develop the codebook, the research team developed a list of engineering design team roles from relevant literature and operationalized definitions for this investigation. In addition to the definitions, the codebook included sample excerpts, behaviors to consider for video data, and examples of what did not count to avoid confusion. The research team coded the same section in the transcript and resolved inconsistencies through conversation. Initial agreement was established (80%), and subsequent coding was completed by a single coder and reviewed by the research team.

Twenty-nine codes were generated from the relevant literature, of which 27 were applied to the data set. Since some codes had few instances during analysis, it made for a more meaningful analysis to group the 27 codes into six categories. This also helps explain trends across and within families with more clarity.

Once all segments were manually coded in Excel, they were verified with the research team. Another member of the research team reviewed and prepared the dataframe for analysis using Python scripts.

Chronological Mapping, Sequence Analysis, Crosstabulation, and Excerpts

Initially, the segments were recorded based on the time they occurred in the recording. These were converted to sequences, as chronological order was more important to the research questions than duration. We used Google Colab and Python/pandas to develop heatmaps, essentially timelines that mapped role codes to utterances in sequence or chronological order. Each utterance was assigned a sequence index, allowing for direct visualization of role transitions within and across families. We also generated frequency distributions and role matrices for the entire data set, by family and by speaker. The same tools were used to perform cross-tabulations and chi-squared tests of roles and design stages, and future work will include tests for significant relationships between them.

The invention process detailed in the Invention Convention curriculum was selected for this study. It is a derivation of the engineering design process but follows a 7-step framework: Identifying a problem, Understanding it through research, Ideating solutions, Designing the invention, Building a prototype, Testing and iterating, and finally Communicating the invention's value. Design stages were assigned based on evidence in the transcript, with utterances reflecting problem definition, brainstorming, planning, building, testing, or explaining assigned to the corresponding design stage. The emphasis of these steps helps to connect the design context to real-world problem-solving, STEM integration, and entrepreneurial thinking. This approach ensured that stage classification reflected participants' observable design thinking rather than assumed progression.

Both quantitative frequencies and qualitative excerpts were analyzed to highlight notable instances of role dominance, transitions, and co-occurrence during project phases. In this study, transcript excerpts and qualitative insights complement the quantitative findings.

Tools of Analysis: Timelines

Chronological mapping was operationalized using heatmaps, which were interpreted as timelines. They are useful visualizations of the role-taking by utterance as the families completed their design sessions. The heatmap timelines enable analysis of role emergence, role dominance, transitions, and pivot instances, and allow comparisons across families and within family units (by speaker). For this study, we did not distinguish between the adults and the children speaking. For each family, all adults' data were merged, and separately, all child data were merged to represent two distinct speaker types.

Blank cells in the heatmaps indicate that no verbal utterances were coded for that family within that specific design stage. This does not necessarily mean that families did not behaviorally engage in that stage. Video recordings of design sessions show that families were actively engaged in design activities, such as building, testing, or transitioning between stages, without verbalizing their reasoning. Working independently on their prototypes, with no verbal utterances, resulted in no transcripts for those design stages. This study relies on transcript-based coding of spoken words, so only verbal evidence of role enactment was represented in the heatmaps.

In some cases, families appeared to transition directly to later stages, such as communication. This reflects the activity's naturalistic and informal nature. Families were not required to explicitly progress through stages in sequence, and some families verbally explained their designs throughout the activity rather than only at the end. Additionally, some early-stage activities may have occurred rapidly or without verbal discussion, resulting in fewer coded utterances in those stages.

Roles Converged to Categories

Initial transcript analysis was enriched by the great diversity and depth of the original coding scheme. However, after initial transcript coding and preliminary analysis, the original 27 role codes (see Table A1) were reduced and converged towards 6 overarching categories (Translators, Champions, Collaborators, Doers, Thinkers, and Leaders) through a thematic grouping process. This convergence enabled clearer identification of overarching patterns within and across patterns and improved quantitative analysis (see Table A2).

Category	Roles
Translators	bridge builder, connector, communicator, facilitator, storyteller
Champions	motivator, cheerleader, encourager, supporter, welcomer
Collaborators	spark starter, problem solver, explorer, team player, collaborator, co-learner
Doers	tinkerer, creative fixer, supply finder
Thinkers	questioner, lifelong learner, guide, user/stakeholder, critic/reviewer
Leaders	teacher/technical expert, mentor/advisor, leader, supervisor/director

Table A1: Role-to-category mapping

Results

Role Dominance Across and Within Families

We wanted to understand which roles were most frequent across the entire dataset and compare them to their emergence within each family unit. Role dominance was calculated as the percentage of role instances across utterances. Table A2. shows the top 16 roles with the most frequently coded roles across the families, with the top five roles being "teacher, technical expert" (11.73%), "tinkerer" (10.84%), "questioner" (10.84%), "team player" (9.33%), and "critic/reviewer" (8.07%). Overall, these dominant roles, along with four of the emergent categories described in our framework: leaders, thinkers, doers, and collaborators.

Disaggregating dominance roles by family enables us to identify which roles are more prevalent in specific families. The role-taking behaviors varied in diversity and dominance. Table A2 presents the top five roles for each family across all instances.

Fam. 6	Leader (16.39%)	Tinkerer (13.11%)	Critic/Reviewer (12.39%)	Teacher/Technical Expert (10.66%)	Supply Finder (9.84%)
Fam. 7	Critic/Reviewer (23.91%)	Teacher/Technical Expert (23.91%)	Supply Finder (13.04%)	Tinkerer (8.70%)	Leader (7.6%)
Fam. 8	Teacher/Technica l Expert (20.47)	Questioner (15.75%)	Encourager (9.45%)	Leader (8.66%)	Supply Finder (7.09%)
Fam. 9	Team Player (40.61%)	Tinkerer (21.21%)	Explorer (18.18%)	Risk-taker (4.85%)	Welcomer (2.42%)
Fam. 10	Storyteller (15.38%)	Questioner (15.38%)	Problem Solver (11.54%)	Teacher/Technical Expert (11.54%)	Tinkerer (7.69%)
Fam. 11	Leader (20.75%)	Tinkerer (15.09%)	Supply Finder (9.43%)	Supporter (7.55%)	Encourager (7.55%)
Fam. 22	Questioner (20.67%)	Mentor/Advisor (13.46%)	Teacher/Technical Expert (11.54%)	Spark Starter (10.10%)	Critic/Reviewer (9.62%)

Table A2: Role distribution among families

Families 6 and 7, for example, exhibited strong leader and Doer orientation, while family 8 represented a more diverse role-taking profile, with the most dominant orientation toward leader roles but also evidence of champion, thinker, and doer role-taking as other dominant roles in their top five. Family 9's profile indicated a high frequency of collaborators role taking behaviors that emerged in the data, followed by doer roles. Family 10 exhibited all roles except the champions, whereas Family 11 combined high frequencies of leader and doer, which indicated collaborative efforts. Family 22 demonstrated strong leader and thinker orientations. These dominant roles aligned with the six categories introduced earlier and illustrate how families embody the diverse roles in their design sessions.

Role Categories by Design Stage

We wanted to understand how families shifted dominant roles as they moved through the design stages. To investigate this, a heatmap was created to show the distribution of the six role categories at each stage. Figure B1 reflects the sample heatmap. We observe that of the seven families, only one was coded for each invention design stage, and two families attended the first two stages. Thinker-oriented roles dominated in the early stages across the families and emerged across. This pattern indicates that families are consistently engaging in questioning, critique, and discovery.

During the 'ideate' stage, roles associated with collaboration, action ("doers'), and leadership began to surface. This emergence reflects a dynamic process of negation and communication participation described in the theoretical framework, as family members transition from exploratory behaviors to collective problem-solving and shared responsibility.

In the design stage, which is characterized by decisions around how the solution will look, feel, and work, leaders, thinkers, and collaborators again emerge, pointing to the need to demonstrate technical expertise, project management, and adaptive role transitions.

The build stage shows the highest prevalence of the leader orientation, with four of six families showing dominance in this role. Rather than solely engaging in hands-on instruction, this pattern suggests ongoing negotiation and expertise sharing – a process that is central to collaborative work

As families move towards the testing stage, which involves analyzing the pros and cons of the prototype and making modifications, the four families that were previously leader-dominant are now oriented towards doers, thinkers, and collaboration, while one family transitions to the champion role. As the family evaluates the new demands of this stage of the project, these diverse role transitions suggest that the family must adjust to remain engaged.

Finally, in the communication stage, families shift again, with all but one enacting a new dominant role that was not previously observed before. These findings demonstrate how families perceive and respond to the unique requirements of each design stage by enacting different role-taking behaviors consistent with the theoretical frameworks guiding this study.

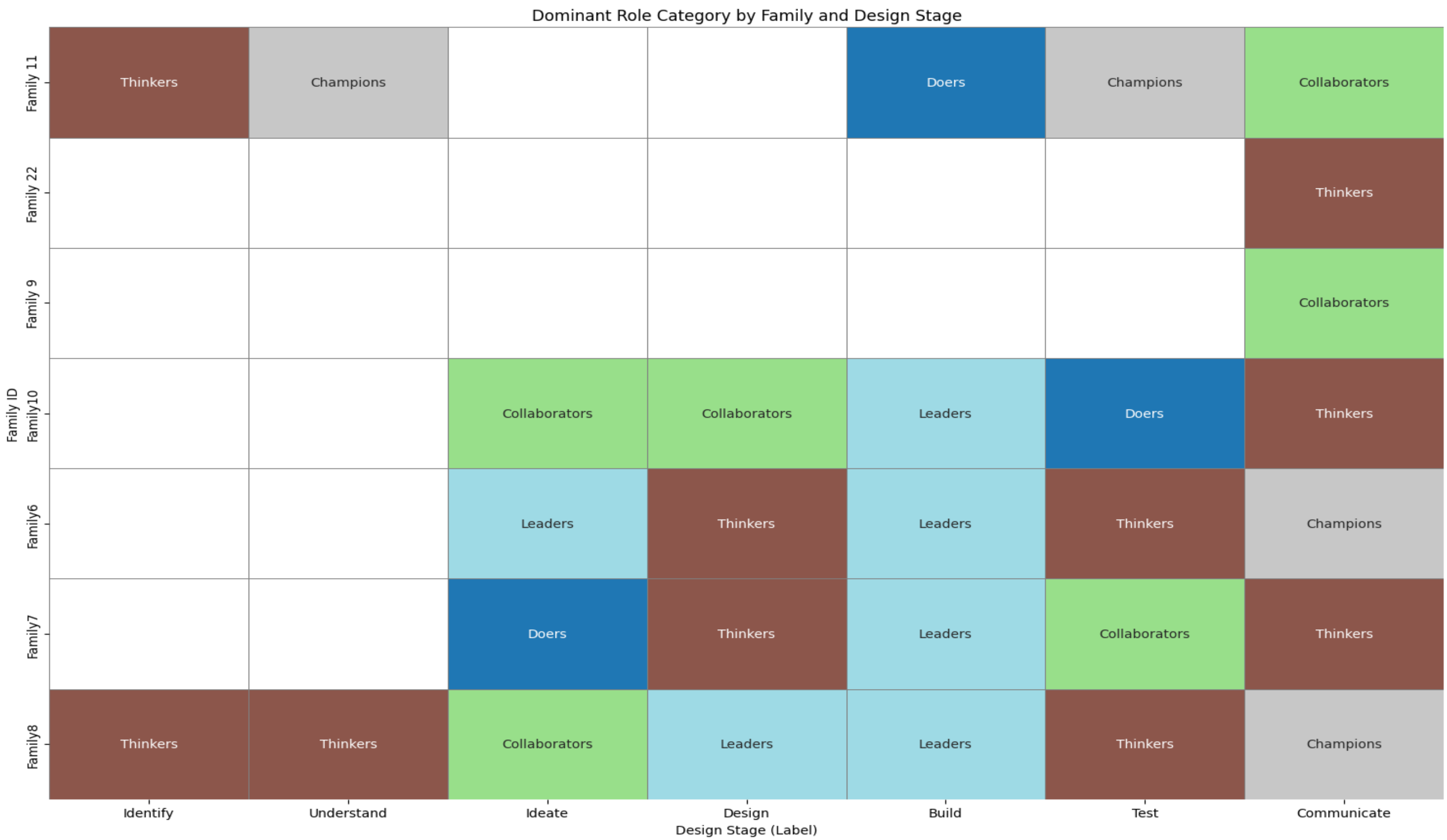

Figure B1: Heatmap showing distribution of role categories at each design stage

Role Categories by Design Stage: Parents Versus Children

To compare role-taking trends by family members, heatmaps were generated for parents and children across design stages.

Champion-oriented roles, which reflect motivation, cheerleading, or supporting the group or individuals within the group, were exclusively observed in the parent heatmaps. Parents also exhibited leadership behaviors more frequently and across more design stages than children, indicating an ongoing negotiation between supporting inquiry and guiding towards project completion.

For children, role-taking in the early stages was sparse, and, as with parents, they adopt thinking-oriented roles. This role-taking aligns with design-process knowledge research, suggesting that, early in the project, designers should ask questions to understand the problem and users' needs.

During the ideate stage, the children predominantly adopted collaboration, leader, and doer roles, while the parents are oriented towards thinker and doer roles. This suggests that parents and children may use different strategies for brainstorming and problem-solving.

In the design stage, parents were oriented towards collaboration, leadership, and thinking roles and activities. While children were primarily oriented towards thinking. In this stage, parents are supportive and engaged, consistent with the framework's perspective of role negotiation and shared tasks.

The build stage revealed the sharpest contrast: parents primarily focused on leadership orientation to complete the project, while children shifted to doer roles, actively constructing the prototypes. Such transitions exemplify situated learning, as the family responds to changing design process needs and alternates between planning and action.

During testing, parents transition from leadership roles and children from doers to a variety of role orientations, which suggests that parents and children are making adjustment decisions as they near the end of the design session. These flexible adjustments indicate real-time learning and collaborative decision-making

In the final communication stage, both parents and children each made a final transition to a new dominant role. Notably, we observe that children demonstrate a translator orientation, making connections between the project and broader contexts as the session nears its end. This behavior is a key outcome in the learning process highlighted by communities of practice theory.

These comparisons suggest that role-taking practices depend on the design stage, and participants must be adaptive. This is a dynamic experience for all participants, and this idea is central to the situated learning framework.

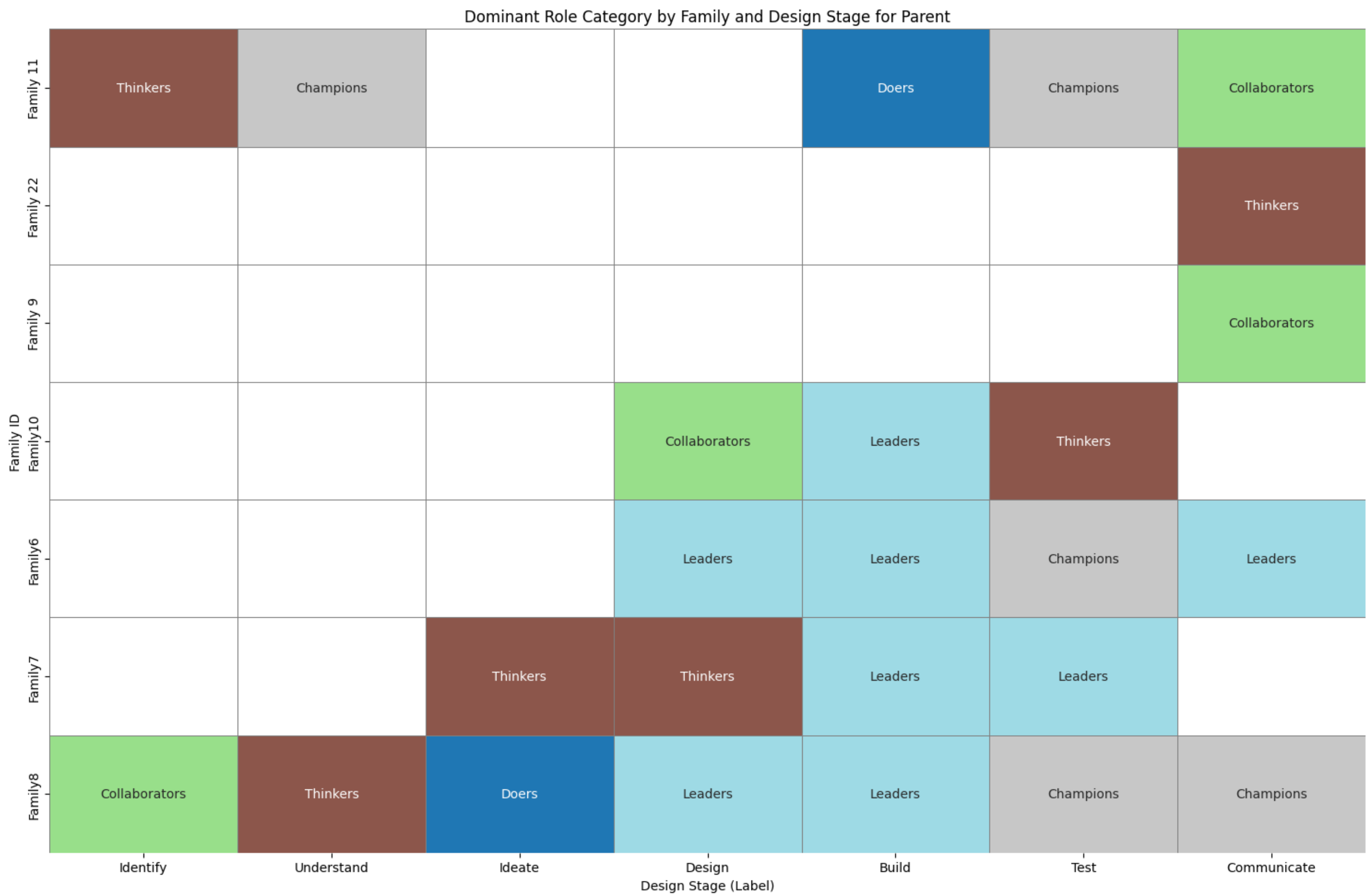

Figure B2: Heatmap showing dominant role categories by family and design stages for parents

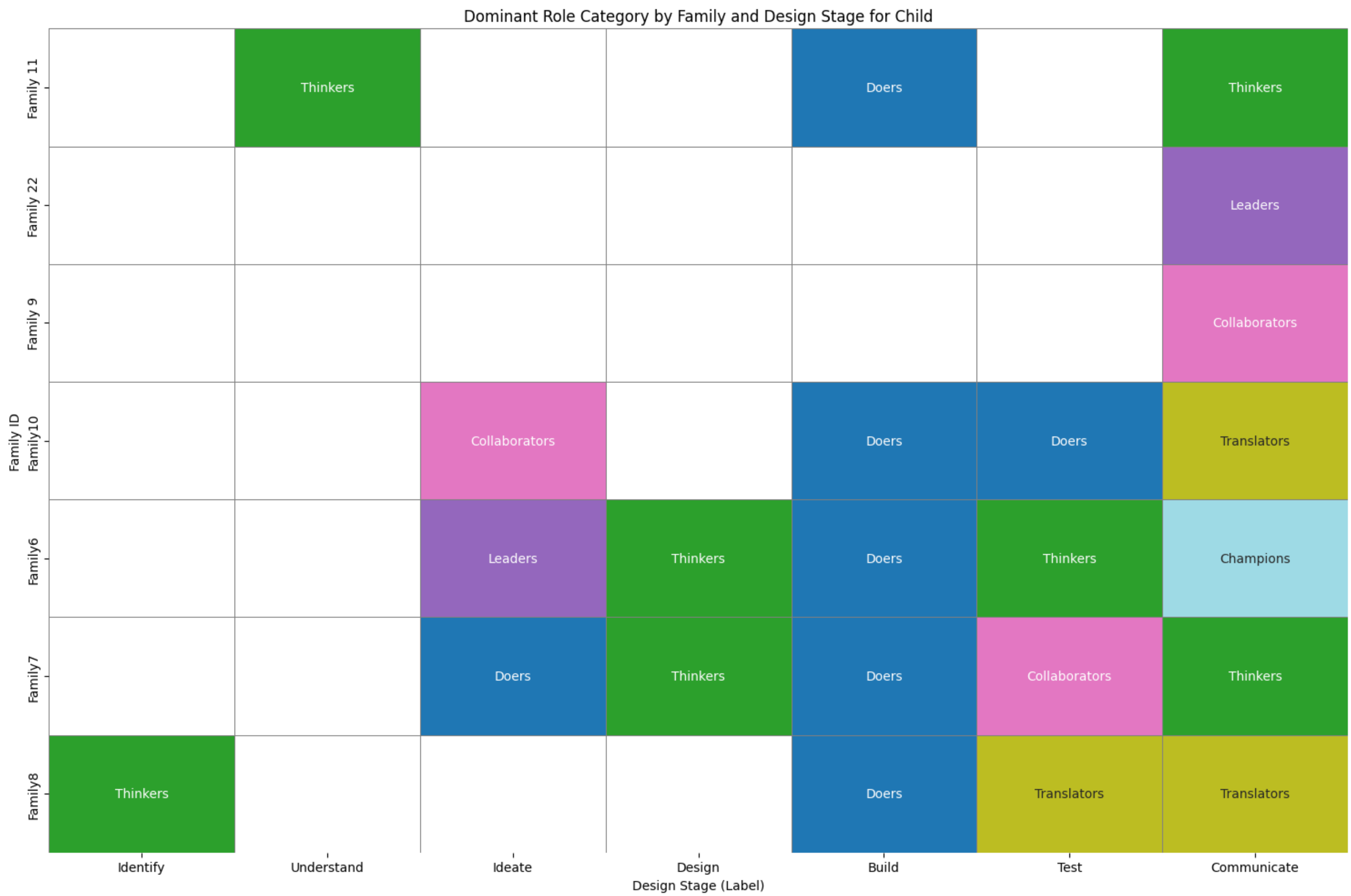

Figure B3: Heatmap showing dominant role categories by family and design stages for child(ren)

Statistical Relationships (Crosstab and Chi-Square)

To analyze the relationship between design stages and the six role categories, we first performed a cross-tabulation to generate a contingency table (see table A3). The table confirmed visual patterns from the heatmaps in the previous section. While families spent limited time in the identify and understand stages, thinker roles were the most dominant (45%) of role-taking in these early stages. Fewer instances in ideate (only 1.9% of all coded utterances) suggest that many families may have started their projects at the design stage rather than engaging in the earlier exploratory stages. Thinker roles remained dominant in the design stage (46.1%). In the build stage, leaders (40.3%) were more dominant than doers (27.3%). The testing stage featured a more balanced distribution of role-taking with champions (21.4%), leaders (23.2%), thinkers (26.8%), and collaborators (17.9%) all well represented. The communication stage saw the highest prevalence of collaborator roles (33.1%), indicating active negotiation of ideas.

Contingency Table: Labels by Role Categories

	Champions	Collaborators	Doers	Leaders	Thinkers	Translators	All
Identify	0	2	1	2	4	0	9
Understand	6	2	1	5	12	0	26
Ideate	1	3	5	3	3	0	15
Design	1	7	11	10	24	1	54
Build	30	14	55	81	20	1	201
Test	12	10	4	13	15	2	56
Communicate	54	143	66	73	85	11	432
All	104	181	143	187	163	15	793

Table A3: Contingency Table - Labels by Role Categories

A chi-squared test of independence assessed the association between the role category and design stage and the test showed a statistically significant association between role category and design stage ($\chi^2(42, N=793) = 156.31, p = 0.000$). Standardized residuals indicated that thinkers in the design stage, leaders in the build stage, doers in the build stage and collaborators in the communication stage occurred at higher-than expected frequencies (residuals >+3). Whereas collaborators and thinkers were underrepresented in the build stage (residuals <-3).

Collectively, these findings suggest that role negotiation is highly dependent on the design stage. Families tend to begin by passing earlier exploration and in the design stage they begin to use thinking activities as action. They then transition to directive leadership in build stages and as they take on diverse roles during the testing phase, they tend to land collaboratively during the communication stage at the end of the session. This overall process is consistent with the ways teams move through engineering projects and situated learning.

Chronological Mapping for Each Family

To provide a deeper understanding of the nuances of role-negotiation in informal family engineering, we present a chronological mapping for Family 8. This case was selected because it included role-taking activities at every design stage and illustrated transitions. Furthermore, there are some interesting transitions that are worth discussing. Figure B4 shows Family 8 heatmap (n = 107 utterances), with shifts observable across the six emergent role categories mapped to the original codes. As a reminder, family 8 represented a more diverse role-taking profile with the most dominant orientation toward leader roles, but evidence of champion, thinker, and doer role taking as other dominant roles in their top five.

Family 8 comprised of two adults (a woman and a man) and two male children (son and cousin). Immediately, upon project initiation, the parents assumed the leader and doer roles, establishing project criteria.

> Dad (leader): Ok, criteria. Scoop must remove the soil. Scoop must work using two fingers when operated. Scoop must pick up one quarter or one half cup of beans. So we gotta take half right here. Quarter cup will be here. Ok. Hold on. So what do we have here?
>
> Mom (doer): We have sticks, cotton balls….

As the session progressed, role negotiation emerged dynamically and rapidly. When child 1 began contributing, he responded directly to a prompt from the male adult, mirroring thinker roles as they clarified the project objective.

> Dad (thinker): "So the key is to identify. What are we trying to do guys?"
>
> Child 1 (thinker): "Make a bean scoop"

Early on, participants—especially parents and Child 1—shifted readily among the six categories, highlighting the fluidity of expertise and participation that is central to Communities of Practice theory (Lave & Wenger, 1991). Mid-session, after an instructor check-in, the children narrated their steps and justified their prototyping decisions, acting as translators of project progress.

> Instructor (thinker): "Oh wow. Tell me about the other ways that you tested before getting to this point "
> Child 1 (translator): "I tried to-. Like this and then took it out. So I could like drop it"

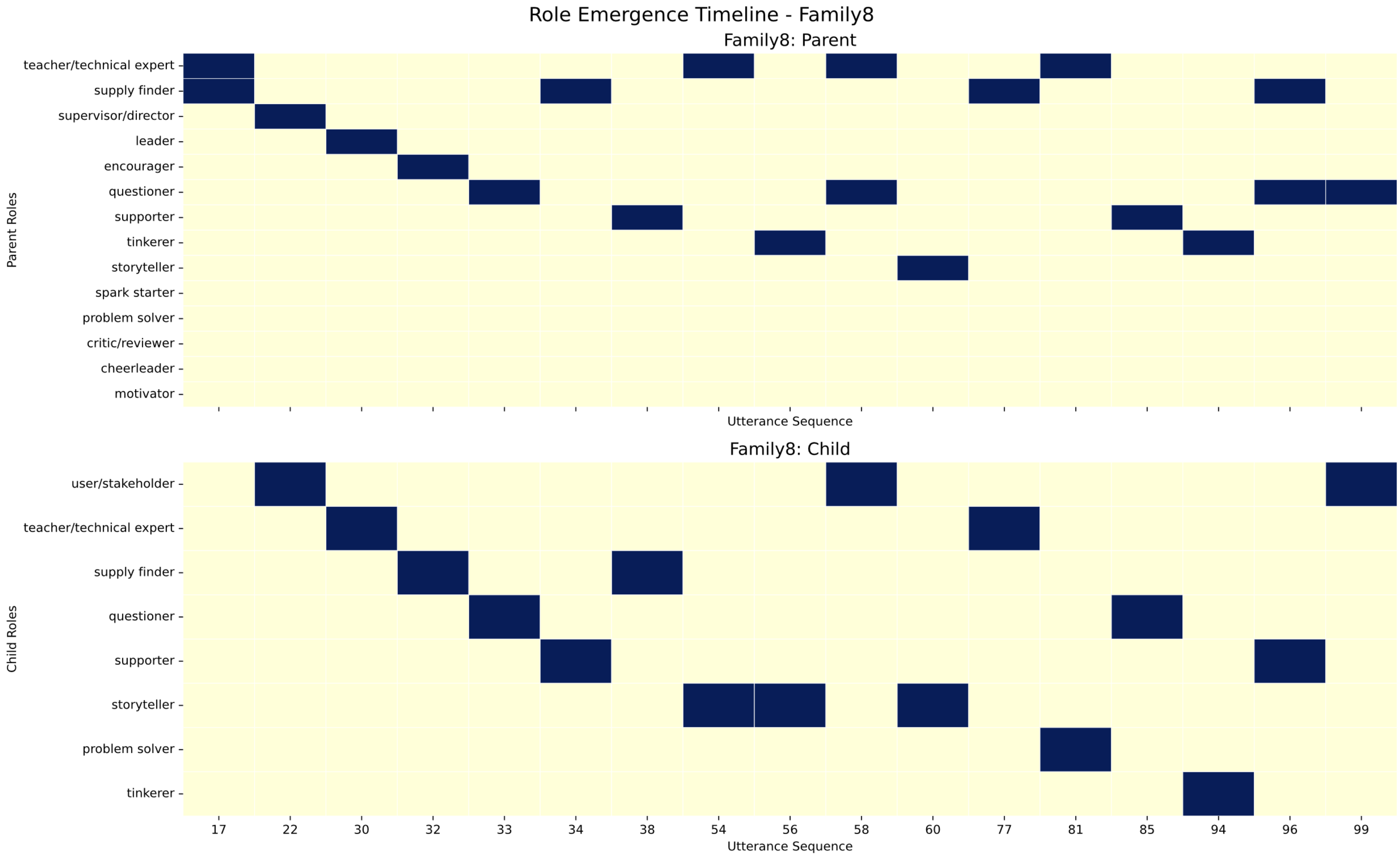

Figure B4: Figure shows role emergence timeline of parents and children in family 8

Throughout the session, the male caregiver is transitioning repeatedly across leadership, questioning and support roles, actively attempting to scaffold the boys learning: across many roles as he tries to also engage the boys in the process.

> Dad (leader): "Look at the tape. the tape is gonna stretch. Dont let it go over the tape. Look more. Look at it there. Sit down, look at that. See that? Now you practice. "

Towards the end of the design session, the children transitioned into doer and thinker roles, while the male guardian alternated between the two throughout. One distinct pattern in this family was that the adults frequently transitioned from teacher/technical expert to questioner or leader, while the children sometimes transitioned from questioner to storyteller. The male guardian provided guidance throughout the session, while the children eventually began to develop agency and showed potential interest in the activity.

This case study illustrates how timelines can capture rapid shifts in focus and the dynamic nature of role-taking negotiation in a design session. The observed transitions reveal how expertise, leadership, support, and engagement are renegotiated throughout the session in response to the task demands. Also, this mapping demonstrates the importance of exploring role-taking trends complemented by transcript analysis to understand the context and experience of the participants.

Discussion and Conclusions

Discussion

This study reveals that family members dynamically negotiate and renegotiate roles as they complete engineering design tasks in informal learning settings. Role-taking patterns were unique to each family yet also reflected broader trends across the dataset. The roles family members adopted were closely tied to the specific demands of the task at a given moment. Families demonstrated flexibility, particularly in the later phases of the design process, with diverse role-taking becoming more apparent in building and testing, whereas fewer families engaged deeply in early-stage activities. The prevalence of leadership and collaboration in build and test stages, and the underrepresentation in early-stage engagement, highlight areas for future exploration.

Chronological mapping exposed shifts in leadership and doer roles in response to evolving task needs. Consistent with Lave and Wenger’s theory, learning was situated and emerged through participation in a community of practice. Families formed such communities as they collaborated to address a drone delivery design challenge. Although the context may not have been immediately relevant to all participants, working together on a real-world problem offered authentic insights into family role negotiation and collaboration.

Conclusions

Family design teams exhibit diverse and adaptive role-taking behaviors, aligning with communities-of-practice theory. This study illuminates the nuanced ways families work together and highlights similarities in how they navigate design stages. Chronological mapping provided powerful visualizations of process and transition, increasing methodological rigor and offering a promising approach for future research in informal STEM learning contexts. These insights may inform how educators and designers develop learning experiences that foster productive collaboration and agency in family-based STEM activities.

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Appendix A

Extracted Roles and Definitions

1. **Bridge Builder (Cultural Broker)** – Helps translate scientific knowledge into a culturally relevant framework, ensuring accessibility for all family members. *(Dani & Harrison, 2021, p. 6)*
2. **Encourager** – Encourages family members to participate in scientific discussions, making them feel valued in the learning process. *(Dani & Harrison, 2021, p. 9)*
3. **Supporter** – Providing encouragement, motivation, and resources to help with the design process.
4. **Motivator** – Encouraging persistence through challenges and celebrating successes.
5. **Perspective Shifter** – Actively works against deficit-based assumptions and fosters strengths-based interactions. *(Dani & Harrison, 2021, p. 12)*
6. **Tinkerer** – Explores ideas through trial-and-error, emphasizing hands-on learning. *(Bevan et al., 2015, p. 14)*
7. **Risk-Taker** – Encourages experimentation and learning from failure without fear of making mistakes. *(Bevan et al., 2015, p. 18)*
8. **Connector** – Connects school-based learning with out-of-school STEM experiences. *(Bricker & Bell, 2014)*
9. **Cheerleader** – Helps reinforce a family member's STEM identity by recognizing and validating their interests. *(Bricker & Bell, 2014)*
10. **Spark Starter** (**Curiosity Catalyst)**– Sparks children's interest in STEM by asking thought-provoking questions or telling them to try something new or challenging. *(Milner-Bolotin & Marotto, 2018, p. 10)*
11. **Problem Solver (Barrier Breaker)** – Helps children overcome learning challenges by simplifying complex topics. *(Milner-Bolotin & Marotto, 2018, p. 14)*
12. **Welcomer (Equity Advocate)** – Ensures that all participants have access to materials and opportunities to engage. *(Vossoughi et al., 2018, p. 8)*
13. **Team Player** – Encourages collaboration by helping family members understand each other's perspectives. *(Vossoughi et al., 2018, p. 10)*
14. **Community Helper** – Engages with the local community to ensure that STEM projects are meaningful. *(Calabrese Barton et al., 2018)*
15. **Creative Fixer (Social Innovator)** – Uses STEM knowledge to address real-world social issues. *(Calabrese Barton et al., 2018)*
16. **Support System (Emotional Anchor)** – Provides reassurance and motivation to persist in STEM despite challenges. *(McDonald et al., 2018, p. 18)*
17. **Guide (Pathway Guide)** – Helps children navigate STEM career opportunities. *(McDonald et al., 2018, p. 22)*

18. **Exploration Guide/Explorer** – Discovery and exploration within and beyond the current project context. New or playful uses of current knowledge and materials. This might look like a side project.
19. **Lifelong Learner** – Models curiosity and continuous learning in STEM.
20. **Critic/Reviewer** – Offering indirect or direct constructive feedback on designs, functionality, and feasibility.
21. **Leader** – This person ensures that they are making progress or redirects attention to the current task (Smith 2025, p4) could be with respect to acquiring materials, setting up workspace
22. **The Supply Finder (Resource Finder)** – Identifies and gathers materials needed for building and testing prototypes. *(Bevan et al., 2015, p. 16)*
23. **Mentor/Advisor** – Sharing professional knowledge, experiences, or technical skills that inspire or inform the design process and can help in problem-solving.
24. **Storyteller** – Sharing personal experiences or historical examples that inspire or inform the design process and can help in problem-solving.
25. **User/Stakeholder** – Representing the end-user perspective by evaluating usability and effectiveness.
26. **Teacher/Technical Expert** - Providing instruction or acting as a STEM guide/Role model during a design task. Demonstrating how to complete a task.
27. **Questioner -** asks questions about their role, the project, materials, or technical information
28. **Collaborator –** Actively participating in brainstorming, prototyping, or testing solutions.
29. **Co-learner -** Evidence of co-learning could be asking questions of each other

Meta Roles

Translators	Champions	Collaborators	Doers	Thinkers	Leaders
bridge builder	*motivator*	*spark starter*	*tinkerer*	*questioner*	*teacher/technical expert*
connector	*cheerleader*	*problem solver*	*risk-taker*	*lifelong learner*	*mentor/advisor*
communicator	*encourager*	*explorer*	*creative fixer*	*guide*	*leader*
facilitator	*supporter*	*team player*	*supply finder*	*user/stakeholder*	*supervisor/director*
storyteller	*welcomer*	*collaborator*		*critic/reviewer*	
the perspective shifter		*co-learner*			