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Cooking up STEM: Adding wh-questions to a recipe increases family STEM talk

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ABSTRACT

Everyday activities such as cooking a meal are natural opportunities for "challenging" family talk, which promotes cognitive development by prompting explanations and elaborations. Our study investigates a light intervention to increase the frequency of challenging family STEM talk during an everyday activity. Sixty-two families with children (mean age = 9.49) recorded their conversations while popping popcorn using either a standard recipe or a recipe with embedded wh-question prompts (e.g., *Why did some kernels not pop*?). Conversations were transcribed and coded to measure four qualities of challenging STEM talk: STEM words, STEM explanations, spontaneous questions, and elaborations (or interactive turn-taking). The results demonstrate that families who received wh-question prompts embedded into the recipe produced 3–5 times more instances of challenging STEM talk than families who received no prompts. These results provide evidence for a light intervention that increases family STEM talk through a familiar, everyday activity.

Children's experiences outside of school provide rich opportunities for engagement with STEM (Rogoff, Dahl, & Callanan, 2018). Everyday experiences such as visiting a museum (Bustamante et al., 2020), visiting a grocery store (Ridge, Weisberg, Ilgaz, Hirsh-Pasek, & Golinkoff, 2015), or cooking a meal (Leyva, Weiland, Shapiro, Yeomans-Maldonado, & Febles, 2021; Morris, Zentall, Murray, & Owens, 2021) allow children and their caregivers to have conversations that increase children's knowledge, vocabulary, and cultural understanding (Hassinger-Das et al., 2020; Zosh et al., 2018) and such activities can be leveraged to augment STEM engagement (Gaudreau, Bustamante, Hirsh-Pasek, & Golinkoff, 2021). Family talk is one mechanism for enriching children's everyday experiences by promoting conversations about STEM (Anderson, Graham, Prime, Jenkins, & Madigan, 2021; Rowe, Turco, & Blatt, 2021). "Challenging" family talk, or talk that prompts explanations and elaborations, supports cognitive development (Anderson et al., 2021). Challenging family talk fosters better memory of events (Haden et al., 2014) and increases STEM learning (Booth, Shavlik, & Haden, 2020; Fender & Crowley, 2007). This paper describes an intervention to increase the frequency of challenging family STEM talk that includes STEM words, explanations, and elaborations, or interactive and detailed conversations characterized by substantive turn-taking (Fivush, Haden, & Reese, 2006; Melzi, Schick, & Kennedy, 2011). This cooking-based intervention provides an example of applying research on cognitive development to create an evidence-based, scalable, low-cost intervention for family STEM engagement that builds upon familiar, everyday activities.

Family talk.

Family talk is a developmental mechanism (Rowe, Leech, & Cabrera, 2017) that promotes language and cognitive development in children (Anderson et al., 2021), provides cues for children to engage in and elaborate upon questions and statements (Haden et al., 2014; Jant, Haden, Uttal, & Babcock, 2014), and helps children sustain their interest in STEM (Dou & Cian, 2021). Family talk is inherently social and places positive demands on a child's attention and cognition, particularly when talk is responsive to a child's actions (Golinkoff, Hoff, Rowe, Tamis-LeMonda, & Hirsh-Pasek, 2019). In this way, investigating the nature of family talk and child talk provides an important foundation for understanding the social contexts in which children develop. Family STEM talk helps children engage with and sustain their STEM interest and identity. For example, US middle school students often show a decline in

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STEM interest, which is often larger for girls and students from underserved communities (Butler-Barnes, Cheeks, Barnes, & Ibrahim, 2021; Djonko-Moore, Leonard, Holifield, Bailey, & Almughyirah, 2018; Liu, Brown, & Sabat, 2019). Middle-school children were more likely to sustain interest in STEM when their families engaged in informal STEM experiences (Bonnette, Crowley, & Schunn, 2019). In addition, the strongest predictor of positive STEM identity in Latine college STEM majors was family STEM talk when these students were ages 5–9 (Dou & Cian, 2021).

Family talk is a malleable factor that can be increased through targeted interventions (Leech & Rowe, 2021). For example, when caregivers were given feedback on their conversations with infants (e.g., having a coach suggest effective strategies for facilitating conversation and turn-taking), caregivers increased the quantity (e.g., number of utterances) and quality (e.g., diversity of words used) of their talk, which increased their child's language skills at 18 months, even when controlling for SES (Ferjan Ramírez, Lytle, & Kuhl, 2020). Families increased the number of conversational turns when caregivers were given prompts, such as future events or open-ended questions, that increased conversations about abstract concepts (Leech & Rowe, 2021). Interestingly, the quantity of talk provides less impact on children's cognitive development than the degree to which talk is challenging. Specifically, talk that is more complex (e.g., wider vocabulary; Anderson et al., 2021), cues children to elaborate (Haden et al., 2014; Marcus, Haden, & Uttal, 2017), and supports the construction of causal explanations (Booth et al., 2020; Letourneau, Meisner, & Sobel, 2021), is associated with greater gains for children. The following section will discuss the characteristics of challenging STEM talk.

Challenging STEM talk

Challenging family talk includes cognitive and social features (e.g., social interactions; Rowe, 2018), though the boundary between cognitive and social features is fuzzy. For example, a caregiver who asks her child a question might prompt a positive cognitive challenge to go beyond the information given, but the social context in which the question is asked, as well as follow-up questions and responsive information support, is social. We define challenging STEM talk as conversations that have four qualities: *STEM vocabulary*, *explanations*, *questions*, and *elaborations*, or detailed and longer conversational narratives (Melzi et al., 2011). Vocabulary, questions, and explanations are cognitive features because the presence of these features provides positive challenges for cognitive development (Cartmill, 2016). Vocabulary input is important because hearing words used informatively (i.e., supported by contextual cues) is a strong predictor of their acquisition (Cartmill et al., 2013). Children who hear more STEM words have larger STEM vocabularies, and early STEM talk is associated with higher academic performance (Tenenbaum, Snow, Roach, & Kurland, 2005). A program that increased the number of STEM words children heard was associated with significant increases in kindergartners' STEM vocabularies (Parsons & Bryant, 2016).

Challenging talk includes questions and explanations, particularly causal explanations (Wellman, 2011). Children's questions and self-generated explanations are important in the construction of their understanding of the world (Legare, Sobel, & Callanan, 2017; Rittle-Johnson, Saylor, & Swygert, 2008). Children develop within a social context that provides opportunities for engagement and learning from others. Caregivers often generate explanations when talking to children. Children's questions to others often cue explanations (Callanan & Oakes, 1992), and children's questions often prompt explanations from caregivers (Castañeda, 2023; Chouinard, Harris, & Maratsos, 2007; Kurkul & Corriveau, 2017). Family talk, particularly talk that includes open-ended wh-questions (e.g., *Why does a wide base make a building sturdy?*), helps children construct and remember new knowledge (Haden, 2010) and pushes children to go beyond the information given (Rowe et al., 2017). Wh-questions are also associated with increasing children's information-seeking and facilitating the construction of their causal explanations (Callanan, Castañeda, Luce, & Martin, 2017; Legare et al., 2017).

Challenging STEM talk also includes responsive, contingent social interactions (Rowe, 2018). One example is the presence of elaborations, or interactive and detailed conversations characterized by substantive turn-taking (Fivush et al., 2006; Melzi et al., 2011). Wh-question prompts were associated with more elaborate family talk that included observations and explanations (Eberbach & Crowley, 2017). Providing challenging conversational demands has been associated with increases in child vocabulary and explanations (Leech, Salo, Rowe, & Cabrera, 2013). The cycle of question-explanation-follow-up in elaborations is a powerful mechanism through which children learn (Kurkul & Corriveau, 2017). Elaborations that are more detailed, include longer narratives (Melzi et al., 2011), and spontaneous prompts for elaboration have been documented in family talk across many cultures (Neha, Reese, Schaughency, & Taumoepeau, 2020; Wu & Jobson, 2019).

One key element in challenging STEM talk that helps to prompt the features described above are wh-questions (e.g., *What kind of animal is that?*; Rowe et al., 2017). Wh-questions cue elaborations because they are open-ended questions that often prompt longer and more detailed responses, rather than simple yes or no responses (Fivush et al., 2006; Haden et al., 2014). More frequent use of wh-questions by mothers was associated with larger child vocabularies (Cristofaro & Tamis-LeMonda, 2012). There is extensive evidence that the use of wh-questions provides opportunities for children to engage in reasoning and set up conversations that direct attention to relevant features, provide just-in-time explanations, and generate predictions (Eberbach & Crowley, 2017; Haden et al., 2014). One important feature of challenging conversations is sustaining the topic across multiple utterances, which allows for multiple opportunities to focus on a topic (Rowe, Coker, & Pan, 2004). For example, posing a wh-question elicits responses from children, which often lead to further conversational turns, and caregiver prompts in the form of questions drive children's follow-up statements more than caregiver statements (Eason, Nelson, Dearing, & Levine, 2021). Such questions can take the form of pedagogical questions, for which the questioner knows the answer, or information-seeking questions that do not require "correct" answers (Daubert, Yu, Grados, Shafto, & Bonawitz, 2020; Yu et al., 2018). Although both types of questions promote learning, information-seeking questions might be more useful in interventions in that they do not require background knowledge or training on the part of the questioner (often a caregiver).

Designing an intervention to promote challenging STEM talk

The evidence presented above demonstrates that family conversations are a powerful mechanism to increase STEM talk, particularly children's STEM talk. In addition, family STEM talk is a malleable factor that can be promoted through conversations that include wh-questions. The intervention described below was designed to leverage the cognitive and social mechanisms described above with three goals in mind: (1) create a light intervention that is potentially scalable; (2) create an intervention built upon an everyday activity, cooking; and (3) design a strengths-based intervention.

One important question is how to promote family talk, particularly talk about STEM content, without requiring significant burdens related to cost and time. We use the phrase *light intervention*[1] to describe interventions that are low-cost, provide minimal support, and are potentially scalable. The efficacy of light interventions has been demonstrated in previous research (see Hassinger-Das, Zosh, Bustamante, Golinkoff, & Hirsh-Pasek, 2021 for a discussion). In one such study, researchers

[1] We acknowledge that others use phrases such as "light touch intervention". We suggest light intervention as a more accurate description because it refers to the relatively light amount of effort, cost, and time in the intervention.

posted signs at the entrance of each supermarket encouraging caregivers to talk to their children and provided specific conversation prompts for half of participants (e.g., *Where does milk come from?;* Ridge et al., 2015). The results demonstrate that the presence of prompts increased family talk for low-SES families, but not for mid-SES families. A similar study was conducted targeting family math talk, in which researchers posted signs in supermarkets promoting general conversations, and posted other signs that promoted math talk (Hanner, Braham, Elliott, & Libertus, 2019). The results indicated that signage with math prompts (e.g., *How many eggs are in a carton?*) was associated with significantly more family math talk than signs with either general prompts or no prompts.

Playful learning spaces in public areas such as libraries and bus stops are another example of this approach (e.g., Hassinger-Das, Bustamante, Hirsh-Pasek, & Golinkoff, 2018). In one study, a library area was constructed to provide children with play opportunities with words and letters (e.g., climbing wall decorated with letters; Hassinger-Das, Palti, Golinkoff, & Hirsh-Pasek, 2020). Families who visited these play spaces engaged in more challenging family talk than families who visited libraries without such spaces. Another example is a large-scale STEM board game in a children's museum that encouraged families to engage in conversations about STEM concepts (Bustamante et al., 2020). In this exhibit, children rolled large dice emblazoned with fractions as part of a math board game. The results demonstrate that families who engaged with this play space produced a higher quantity of and more challenging family STEM talk than those who visited a traditional STEM exhibit at the same children's museum.

A second goal for intervention design is to focus on everyday activities with potential to provide rich learning opportunities. Everyday activities are inherently meaningful, have a familiar event structure, and provide background knowledge often lacking in formal, school-based learning activities (Rogoff et al., 2018). Cooking is a culturally-rich context, an everyday activity, and a valuable life skill that creates opportunities for positive social interactions within families (Leyva et al., 2021; Morris et al., 2021; Vandermaas-Peeler, Way, & Umpleby, 2003) and a rich context for STEM integration (Vandermaas-Peeler, Boomgarden, Finn, & Pittard, 2012). Previous projects have demonstrated the potential for family engagement through cooking-based activities. An afterschool cooking and nutrition program serving food-insecure families significantly increased nutrition knowledge, healthy eating, and cooking self-efficacy (Tørslev, Bjarup Thøgersen, Høstgaard Bonde, Bloch, & Varming, 2021). Caregivers appear to add some STEM content to many everyday activities, including cooking, though these tend to be a small number of instances overall (Vandermaas-Peeler, Westerberg, Fleishman, Sands, & Mischka, 2018). Adding specific prompts to these activities, such as prompts for counting during a cooking activity, increased these opportunities and improved the math performance of preschool children who received them (Vandermaas-Peeler et al., 2012). A culturally-sensitive intervention for Latine families added opportunities for math engagement in food routines such as grocery shopping and cooking (Leyva, Davis, & Skorb, 2018). For children with lower scores at pre-test, higher levels of family participation in the intervention were associated with relatively larger gains in math skills at post-test. A later iteration of this intervention that promoted caregiver-child talk (e.g., math talk), reading, and writing in Latine families was associated with increases in child vocabulary and executive function scores (Leyva et al., 2021). The results of these studies demonstrate the potential of leveraging the everyday activity of cooking as an opportunity for STEM engagement.

Strengths-based approaches begin with the understanding that individuals, families, and communities have assets such as knowledge, skills, and motivation that can be built upon (Castañeda, Callanan, Shirefley, & Jipson, 2022; Melzi & McWayne, 2023; Rahm & Moore, 2016). This approach begins by identifying strengths present in individuals, families, and communities. Curiosity is ubiquitous in children's development, though its expression varies across cultures in forms such as verbal expressions (e.g., spontaneous wh-questions) or participation in shared activities (Gauvain, Munroe, & Beebe, 2013). There is also evidence of widely-shared beliefs that caregivers should promote education and learning for their children, though this too shows considerable cultural variation (Guo, 2013).

Creating a strengths-based approach for specific communities first requires the identification of these strengths. One example of a project that identified and built upon such family and community-based strengths is a series of food-related interventions designed with Latine families to leverage family routines for engagement and learning (Leyva et al., 2018, 2021). In this project, the team identified food narratives and routines and designed an intervention to build upon these strengths; in this case, the intervention provided strategies for caregivers to enhance children's narratives.

The present project emerged from a larger project on informal STEM learning and working with food-insecure families. Notably, little research is available investigating informal STEM engagement in food-insecure populations. One reason is that food-insecure families are often isolated from settings in which such experiences are typically investigated (e.g., museums). We identified strengths based on findings from the literature and through the experience of our community partners. The results from the limited evidence in the literature (Higashi et al., 2017; Rosemond et al., 2019) were consistent with the strengths identified by our community partners. Both identified two strengths in food insecure families: (1) the centrality of family time and (2) the importance of centering community, sharing, and family during meals and cooking (Higashi et al., 2017; Rosemond et al., 2019). Based on these findings, we created our intervention to focus on three strengths: (1) building upon child curiosity, (2) supporting caregivers in engaging their children, and (3) centering family interactions during a cooking activity.

Present study

The present study tests a light intervention that uses wh-questions to leverage cognitive (e.g., promoting explanations) and social mechanisms (supportive social interactions) to promote children's STEM talk (Kurkul & Corriveau, 2017; Rogoff, 2003) in the familiar, everyday activity of cooking. Our project includes two unique features that have the potential to contribute novel findings. First, we implemented a light intervention in which half the families were given a popcorn-popping recipe with three embedded wh-questions. We term this a "light intervention" because the amount of structure provided is minimal and there was no monitoring of participants by the research team to ensure fidelity of the intervention. In this way, a light intervention is naturalistic in that a few prompts are embedded with an everyday cooking activity. The benefits of light interventions are that they require little time and resources for research teams and participants. The challenge is that such interventions provide risks such as insufficient dosage of treatment and low fidelity of implementation. For these reasons, research should focus a light intervention on an efficacious target variable. In sum, the intervention might be light, but the science behind it is not.

Second, the recruitment process required a novel approach because the population was widely geographically distributed and because data collection occurred during the COVID-19 pandemic. We distributed a container with popcorn kernels and oil to hundreds of families as part of a community food distribution event. This event focused on food-insecure families, who were each given a box that included books, shelf-stable foods, recipes, and the popcorn container. Interested families scanned a QR code on the popcorn container that led them to information about the study. Once families completed a consent and demographic form, they were given instructions to record their family conversation while popping popcorn. Half of the families were given general instructions to ask questions during the activity. The other half were given the same instructions and provided three wh-question prompts in the recipe to ask during the activity (e.g., *What do you smell while the popcorn is popping?*). We hypothesized that the specific prompts would be associated with more qualities of challenging STEM talk compared to families who did not receive the prompts. Specifically, we hypothesized that the presence of wh-questions would increase the number words used, explanations, and elaborations.

Method

Participants

The experiment was approved by the Kent State University IRB. A total of 62 families participated in the experiment who were randomly assigned to either the control or experimental group (explained below). All families who participated in the study were native English speakers. Three families had two children participating in the activity, for a total of 65 children in our sample. All children who participated were between the ages of 6 and 11. Mean ages of the children in the Experimental group was 9.65 (SD = 0.85) and 9.33 (SD = 1.39) in the Control condition. Most of the adults in the activity self-identified as parents/guardians (54/62) with the remaining adults identifying as grandparents (8/62). Parents provided consent for 63 of the children in the study, including five children who completed the activity with a grandparent, while custodial grandparents provided consent for two children. See Table 1 for additional demographic information.

In addition to the 62 families who participated in the study, six additional families were recruited so that their conversations could be used to reach reliability on coding. These families participated in the same way as families in the experiment. Each family was given a $25 Amazon gift card for participating.

Recruitment

Participants were offered food kits as part of a series of food distribution events in the Cincinnati, OH region. These events were advertised in local media and ads that focused on food-insecure communities in the region. Approximately 700 food kits were distributed during the four days of the events. The food kits included shelf-stable food products, children's books, and a special container with popcorn kernels and vegetable oil for this study. This container was affixed with a label that included a QR code and the following message: "Scan the QR code to participate in the Popcorn family fun activity and earn a $25 Amazon gift card!" The QR code took potential participants to a landing page that provided information about the popcorn family fun activity, the nature of participation, and the financial incentive, a $25 Amazon gift card. A total of 126 families scanned the QR code, and 74 families began the consent form. Of these families, 65 families completed the popcorn activity. Three families did not submit a usable audio file. These families were contacted but did not respond or send the audio file. All 65 families were compensated for their participation.

Table 1
Family demographics.

Characteristic	Experimental		Control	
	n	%	n	%
Child Gender				
Girl	20	59	15	48
Boy	14	41	16	52
Family Race/Ethnicity				
Asian-Pacific Islander	5	16	1	3
African-American	10	31	13	43
White	17	53	16	54
Adult Role				
Parent	28	87	26	87
Grandparent	4	13	4	13

Procedure

Families first completed an online consent form and a demographic questionnaire through Qualtrics that included information about the gender, age, race/ethnicity, and family zip code of each participant. Families who consented to participate were given a URL for the activity landing page and instructions about how to prepare for the activity (reminder of ingredients in the kit). They were instructed to open the landing page when they were ready to begin popping popcorn. Once they opened the landing page, they were asked to enter their surname as a way to check that the family had consented to participate. Then, families were randomly assigned to one of two groups: control or experimental (recipe with wh-questions). Participants were blind to condition. Participants in both groups saw identical information about ingredients, the recipe for making popcorn, and a general statement encouraging asking questions while making popcorn ("Talking to your child helps them learn! Remember to talk about what you are doing and ask questions while you make the popcorn!"). In the experimental group, a statement encouraging asking questions included this passage to note specific questions to be asked: "To help out, consider using some of the questions provided below, but do develop some of your own too!". Three wh-questions were embedded into the recipe (in all capital letters to increase salience) to provide prompts for starting conversations at appropriate times during the cooking activity (see full instructions in supplementary materials). For example, after the step of pouring popcorn into a bowl, the question prompt was, "Why did some of the kernels not pop?" The wh-questions included in the experimental group were purposefully selected to direct attention and convey curiosity (see Fig. 1).

Participants were asked to record the conversation either on a device in the home such as a smartphone or tablet or by using a recording stick that researchers provided (no participants used the recording sticks). Participants were instructed to begin the recording before they started making popcorn and stop recording after they finished popping it. Participants emailed the sound files to the first author, which were stored in a secure, password-protected drive.

Transcription

The audio files were initially transcribed using Otter, an online transcription platform. The resulting transcripts were then checked for accuracy and formatted for coding by the research team following the CHAT guidelines in the Child Language Data Exchange System (CHILDES) database (MacWhinney, 2000). The transcribed conversations were formatted so that the Computerized Language Analysis (CLAN) program from the Child Language Data Exchange System (CHILDES) database (MacWhinney, 2000) could be used with the transcripts. The CLAN program is a free program that was specifically designed to analyze data when the transcript is formatted according to specified conventions. To format the transcripts for these conventions, the family talk was categorized into utterances. We followed Eason et al. (2021) to define an utterance as speech bounded by syntax, intonation, or a pause of 2 s or greater by the speaker. Once properly formatted, transcripts could be searched and features quantified using the CLAN program (e.g., the total number of unique words). As described below, analysis was conducted on both the word and utterance level.

Word level

We first measured the number of unique words produced by each individual speaker in the transcript. We used the FREQ command in the CLAN program system to count the total number of words used by each speaker. We then manually coded and counted all STEM words produced by each speaker to quantify the total number of STEM words and the total number of unique STEM words by speaker (see details below).

Fig. 1. Screenshot of instructions for experimental group.

Utterance level

We also examined talk at the utterance level produced by each speaker (i.e., child or caregiver). We first used the CLAN system to count the total number of utterances by the child and by the caregiver individually. We then manually coded all utterances to determine whether it was STEM-related or non-STEM-related. STEM-related talk is discussed in detail in the descriptions below. To better understand the type of talk that families engaged in, we further categorized non-STEM talk into task-related and non-task utterances. Task-related (non-STEM) utterances refer to talk that is relevant to the task but doesn't necessarily convey STEM content (kappa = 0.985). Examples of this include following the recipe ("It says to turn the oven on medium"), outlining next steps in the process ("Next, we put in the rest of the popcorn"), and safety instructions (e.g., "Be careful, the burner is hot!"). Utterances that were coded as non-task related (non-STEM) refer to talk that is unrelated to both the task and STEM content (kappa = 0.967). An example is a child saying "Hello" or "Thank you" to the people who will hear the recording. Fig. 2 depicts the details of our coding scheme that we used to categorize families' utterances during the popcorn activity.

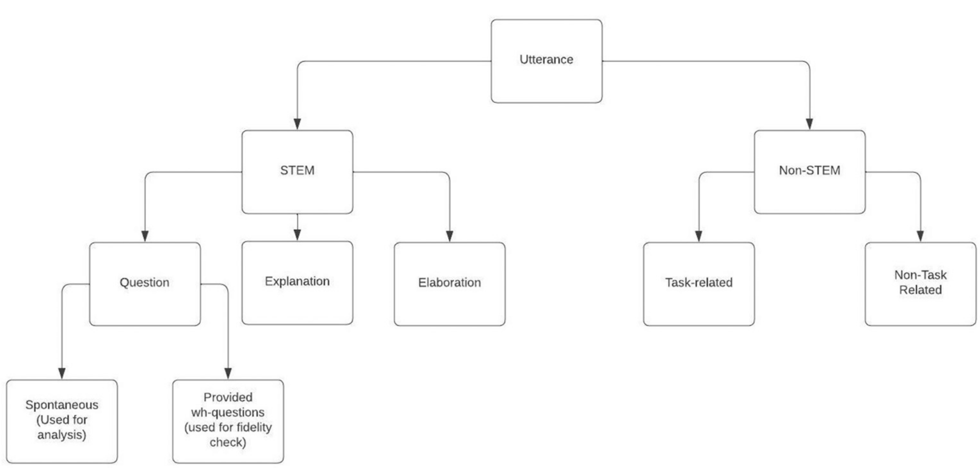

Fig. 2. Utterance level coding scheme.

Coding qualities of challenging family STEM talk

We manually coded four qualities of challenging family STEM talk, one at the word level and three at the utterance level. An overview of the coding categories used to measure the challenging family STEM talk, detailed coding information, and inter-rater reliability indices are summarized below:

Word level

At the word level we coded the number of unique STEM words (e.g., *heat*, *energy*) or words that conveyed causal relations related to STEM content (e.g., *cause*; *because*; *heat makes the popcorn pop*) and which speaker produced this word. We manually coded which individual in the family first used the word. For example, if the word *heat* was used multiple times, but the caregiver was the first one who introduced the word into the conversation, it was coded as a caregiver STEM word. We also coded for the total number of STEM words used by each speaker. In this category, if the word *heat* was used three times, we coded all three instances to illustrate the total amount of STEM talk that the families were engaging in during the activity.

Utterance level

As illustrated in Fig. 2, at the utterance level, we coded STEM talk into three categories. Each utterance was coded by identifying the speaker (caregiver or child).

1. Explanations. We defined an explanation as stating a causal relation related to a task phenomenon (similar to Booth et al., 2020). We coded the number of explanations for each participant (e.g., *The heat makes the popcorn pop*) because providing explanations, particularly just-in-time explanations, promotes children's reasoning about causal relations and improves their understanding of phenomena (Booth et al., 2020).
2. STEM questions. We coded the number of questions that were prompts for attending to features, comparing features, predicting, or generating explanations. Most frequently, these took the form of wh-questions (e.g., *Why does popcorn pop?, What happens if we don't shake it?*) To control for the three questions that were provided to families in the experimental group, we coded spontaneous STEM questions (that were not provided as part of the experiment) separate from the question prompts provided. Including this measure allowed us to more accurately compare the questions used by the families in each of the two groups. We counted the use of the three question prompts provided to families in the experimental group as a fidelity check (at least two of the three prompts indicated fidelity to instructions). Only one of 32 families in the experimental group was classified as not using the question prompts (used 0 of 3 prompts), while 31 of 32 families used at least two of the three prompts. The prompts provided to families were not included in the counts used for further analysis. Thus, the counts used for analysis were STEM-related questions that were spontaneously produced.
3. Elaborations. We also coded the number of utterances in which a speaker responded to a question or explanation from the other speaker. These utterances were coded as elaborations and are related to explanations and questions because previous evidence suggests that such prompts increase the amount of STEM talk and family engagement (Hassinger-Das, Hansen, et al., 2020). Utterances were coded as elaborations if (a) they followed an explanation or STEM question and (b) shared the same topic. An example series is provided below:
   a. Caregiver: Do you notice anything right now?
   b. Child: That looks hot.
   c. Child: There is smoke.
   d. Child: Color looks yellow and they are smaller.

This example would be coded as one STEM question utterance and three elaboration utterances.

The first three authors developed the initial coding rubric using materials from a similar pilot study. Once the initial rubric was established, the first three authors iteratively revised it using six training transcripts coded in three waves, each wave including two transcripts. The first wave evaluated and improved the fidelity of the coding system. The second and third waves improved the coding system and measured the reliability between coders. The team calculated reliability and resolved disagreements in coding meetings. At the end of the third wave, the team calculated reliability for three coders (the first three authors) using Cohen's kappa, resulting in overall agreement at 0.892 before discussion. After reaching this initial level of reliability, 22.5% of transcripts (14/62) were coded by two of the authors to measure inter-rater reliability. For each category, the average kappa for these transcripts was 0.915 before discussion. Kappas for each coding category are included in Table 2 above.

Results

The team conducted an a priori power analysis using G*Power version 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) to estimate the minimum sample size required to test the study hypothesis. Results indicated that $N = 32$ was the required sample size to achieve 80% power for detecting a medium effect, at a significance criterion of $\alpha = 0.05$. Thus, the obtained sample size of $N = 62$ was adequate to test the study hypothesis. The participants were grouped according to the condition, with 32 families in the experimental group (i.e., assigned conversational prompts) and 30 in the control group (i.e., no conversational prompts assigned).

The team conducted statistical analyses in SPSS (IBM SPSS Statistics for Windows, Version 29.0). Prior to comparing the results by group, a series of *t*-tests were conducted to ensure the families in the experimental and control groups did not differ in demographics and language use regarding non-STEM talk. The results suggest that families in the two groups did not differ in child age ($t(63) = 1.661$, $p = .102$), child gender ($t(63) = -0.835$, $p = .407$), family race/ethnicity ($t(60) = -0.733$, $p =$

Table 2
Qualities of challenging STEM talk categories.

Concept	Talk level coded	Coding	Example	Kappa
STEM words	Word	Identifying the total numbers of STEM vocabulary words and unique STEM words	Expand; measure; sizzling	0.910
Explanations	Utterance	STEM explanations that are related to the phenomena in the activity	Child: So, maybe some of them couldn't get the hot air they needed around it to pop.	0.927
Questions	Utterance	STEM-related questions	Caregiver: How does the oil help it pop?	0.933
Elaborations	Utterance	Identifying multiple statements that are linked to the same conversational thread. Elaborations may contain STEM words or explanations.	Caregiver: Why does popcorn pop? Child: I don't know. Caregiver: Does it have something to do with the heat? Child: Yeah, maybe the popcorn has to get hot to explode.	0.886

Note. Kappa level reflects agreement before discussion.

.466), family income ($t(60) = 0.845$, $p = .401$), caregiver role (i.e., parent or grandparent involved; $t(60) = 0.096$, $p = .924$), the number of task-related utterances (i.e., non-STEM cooking-relevant utterances; $t(60) = 0.460$, $p = .647$), and the number of non-task-related utterances (i.e., non-STEM cooking-irrelevant utterances; $t(60) = 1.092$, $p = .279$). Overall, the team observed no significant difference in demographics and non-STEM talk between the experimental and control groups, increasing confidence that the differences in the light intervention were associated with the group.

Next, the team conducted two sets of Kruskal-Wallis tests, due to violations in the Normality and Homogeneity (i.e., counted data), to examine differences in family STEM talk. The independent variable was the group (i.e., control and experimental). The dependent variables were the number of caregiver and child utterances and words (hereafter Quantity measures). In addition, the number of STEM caregiver and child unique words, total words, explanations, questions, and elaborations (hereafter Challenge measures). Furthermore, the team also examined non-parametric partial correlations between the caregivers and children within the specific categories in Challenge (e.g., correlation between the numbers of caregiver STEM explanations and child STEM explanations), controlling for the group.

The team conducted Kruskal-Wallis tests using an alpha level of 0.05 divided by the number of dependent variables (i.e., Bonferroni Correction; $\alpha = 0.0125$ for Quantity and 0.005 for Challenge). Families in the experimental group produced significantly more talk than families in the control group in each category, including the number of caregiver utterances ($p < .001$), the number of child utterances ($p < .001$), the number of caregiver words ($p = .006$), and the number of child words ($p < .001$). Effect sizes were large, except for the difference in the number of caregiver words ($\eta^2[H] = 0.109$; see full results in Table 3 below). The visual layouts of descriptive statistics are presented in Supplemental Materials Figs. 1 and 2.

Our next analyses demonstrated significantly more challenging STEM talk among families in the experimental group compared to families in the control group. Specifically, caregivers and children in the experimental group produced more unique STEM words, more STEM words in total, more STEM explanations, more spontaneous STEM questions, and more elaborations (all $p < .001$; see Table 4 below for full results). Effect sizes were large for all the significant differences. The visual layout of descriptive statistics is presented in Supplemental Materials Fig. 3.

It is possible that the result pattern above might be due to differences in the overall amount of talk in families. For example, if one family produced more words overall, they may also produce more STEM words than a family who simply produced fewer words and utterances. To investigate this possibility, we conducted another series of analyses to control for the overall amount of talk. We first created indices for each challenging talk quality category that controlled for the quantity of talk.

Table 3
Descriptive statistics and Kruskal-Wallis tests in family conversation quantity.

Measure	Experimental		Control		*H*	η^2[H]
	M	*SD*	*M*	*SD*		
Total utterance caregiver	54.50	23.78	31.53	17.53	15.453**	0.241
Total utterance child	27.09	7.83	14.25	6.88	28.869**	0.465
Total words caregiver	377.06	201.88	242.00	143.22	7.545**	0.109
Total words child	138.53	45.94	69.77	40.08	24.172**	0.386

Note. Three families had two children involved. The researchers ran the same tests twice to ensure that including the data of either child for the three transcripts would not affect the overall results significantly. Therefore, the current analyses (include followings) averaged the child data for the three two-child transcripts.
** $p < .01$.

Table 4
Descriptive statistics and Kruskal-Wallis tests in challenging family conversation qualities.

Measure	Experimental		Control		*H*	η^2[H]
	M	*SD*	*M*	*SD*		
STEM unique words caregiver	13.72	4.23	7.23	3.71	24.841**	0.397
STEM unique words child	7.36	3.38	3.02	4.13	23.324**	0.372
STEM total words caregiver	32.34	12.35	10.77	7.51	32.915**	0.532
STEM total words child	19.41	5.98	3.53	2.91	42.143**	0.686
STEM explanations caregiver	4.09	3.81	0.83	1.18	21.080**	0.335
STEM explanations child	2.30	1.47	0.07	0.25	38.950**	0.633
STEM questions caregiver	4.03	2.29	0.87	1.04	34.733**	0.562
STEM questions child	1.42	1.06	0.27	0.45	22.332**	0.356
STEM elaborations caregiver	7.19	4.38	1.20	1.67	34.209**	0.553
STEM elaborations child	8.38	4.64	0.68	0.99	45.281**	0.738

** $p < .01$.

The word-level index divided the number of STEM words by the total number of words produced by speaker type (i.e., caregiver or child). Utterance-level indices divided the number of explanations, spontaneous questions, and elaborations by the total number of utterances produced by speaker type. The pattern of results were nearly identical to the previous results, with higher proportion of STEM words, explanations, spontaneous questions, and elaborations in the experimental group (all $p < .001$ with $\alpha = 0.006$ after Bonferroni Correction; see Supplemental Materials Table 1 for full results). Effect sizes were large for all the significant differences. The visual layout of descriptive statistics is presented in Supplemental Materials Fig. 4.

To further examine the family STEM conversations, we investigated relations between the variables using non-parametric partial correlations for the nine STEM categories identified above: STEM unique words, STEM total words, STEM explanations, STEM questions, STEM elaborations, and the proportions of STEM words, explanations, questions, and elaborations. A within-category correlation means, for example, correlating the number of caregiver STEM explanations with child STEM explanations, controlling for the group (i.e., experimental and control). Statistically significant coefficients were observed in the number of STEM unique words ($r(59) = 0.256$, $p = .047$), the number of STEM total words ($r(59) = 0.380$, $p = .003$), the number of STEM explanations ($r(59) = 0.292$, $p = .022$), STEM word proportion ($r(59) = 0.494$, $p < .001$), and STEM question proportion ($r(59) = 0.436$, $p < .001$; see Supplemental Materials Table 2 for full results).

An additional set of partial correlations were conducted to measure the relations between different qualities of challenging STEM talk (e.g., between STEM the number of questions and the number of explanations/elaborations). Statistically significant coefficients were observed between the number of caregiver STEM questions and child STEM elaborations ($r(59) = 0.541$, $p = .001$), child STEM questions and caregiver STEM explanations ($r(59) = 0.373$, $p = .003$) and caregiver STEM elaborations ($r(59) = 0.554$, $p = .001$), with a non-significant coefficient observed between the number of caregiver STEM questions and child STEM explanations ($r(59) = 0.086$, $p = .511$).

We also conducted a series of correlations to determine if there was a relation between the age of the child and the quantity and qualities of challenging family talk. For example, it is possible that caregivers might engage in more elaborations with older children, compared to younger children. To investigate the age effects, non-parametric partial correlations were conducted between the child age and all the child dependent variables in the Quantity and Challenging Qualities categories, controlling for the group differences. Only one statistically significant coefficient was observed: child age and the number of child total words ($r(59) = 0.313$, $p = .014$), suggesting that older children produced more words overall (see Krethlow, Fargier, and Laganaro (2020) for child age effects on word production). No other age-related correlations were significant.

Discussion

The goal of the project was to test the efficacy of a simple, potentially scalable intervention to increase challenging family STEM talk that involves embedding wh-questions in a recipe for popping popcorn. As noted above, we defined challenging STEM talk as talk that included STEM words, explanations, and elaborations (Fivush et al., 2006; Melzi et al., 2011; Rowe, 2018). All families recorded their conversations while making popcorn on a stovetop, and the team transcribed and coded these conversations to measure challenging STEM talk. The results demonstrate that families given wh-question prompts produced more challenging STEM talk compared with families who were not given these prompts. Below we have provided an example transcript from each condition. The first sample, from family 1, serves as an illustration of the family talk that was common in the experimental condition. The example from family 2 was selected from the control condition to highlight the notable difference between family STEM talk in the two conditions. We will discuss the results using these transcripts as examples from each condition. The differences shown below underscore the potential of this light intervention in strengthening family STEM talk and enhancing children's learning and cognitive development.

Family 1 (Experimental Condition).

Caregiver: Okay, we are here going to try your popcorn challenge. Daddy is first entering how much oil that you put on there. One tablespoon of vegetable oil to three kernels of corn, right? So there's three kernels. Turn the pot to medium heat, medium heat.

Child: Ok. Is this right?

Caregiver: Yes. So we'll wait and then when those kernels pop we put in the rest of the cup. So we got to wait for it to pop then add the rest of the third cup of popcorn kernels and even later.

Child: Can I use a third cup?

Caregiver: Yes, once the kernels pop. What does it say to do when we pour it in?

Child: Pour the kernels in and make a single layer.

Caregiver: Yeah. Add the third cup after this last one pops.

Child: Ok.

Caregiver: Yes. We have here we have some questions we can answer. Well this is the old fashioned way. The old old fashioned way. It's gonna take some time so homeboy, what do you notice? Do you see what do you see hear and smell as the popcorn cooks Do you notice anything right now?

Child: That looks hot. There is smoke. Color looks yellow and they are smaller.

Caregiver: What is smaller you think?

Child: The kernels.

Caregiver: Okay, what is different about the kernels before and after you cook? What do the kernels look like right now?

Child: They are yellow.

Caregiver: Are they hard are they soft?

Child: They are hard. I touched them before we put them in.

Caregiver: Okay. They're starting to bubble a little bit that's good.

Child: Faster bubbles now.

Caregiver: With the movement. I think we get ready to shake popcorn.

Child: Daddy, shake the popcorn.

Caregiver: They still haven't busted through. There's one. We did this one do you think so?

Child: Yeah.

Caregiver: Any growing get bigger?

Child: Oh that's scary. Oh gosh okay all right daddy.

Caregiver: Okay okay, here we go here we go. Under that layer this is hidden layer.

Child: I can't wait to see popping. Oh it's okay.

Caregiver: All right, daddy is shaking back and forth up to here. They said if the popcorn started to pop I do the lid do the lid a little bit. So the steam gets out.

Child: It's going really fast. It sounds good.

Caregiver: All right. It says then once your popping slows to several seconds between pops remove the pan from heat remove the lid and dump the popcorn into a bowl.

Child: Add salt and enjoy.

Caregiver: So what do you what do you hear smell are see now?

Child: The kernels are turning into popcorn.

Caregiver: Okay, kernels are turning into popcorn. What is different between the pot the kernels before and after you cook them? Why do you think that some of the kernels did not pop?

Child: Because they didn't get hot enough.

Caregiver: Okay. All right now what we did is that we noticed like when the we had the three in there that the kernels was getting really big and then we watched it expand and explode.

Child: Yeah, the heat makes it explode.

Caregiver: This is one of her very first science experiments was food. All right. Well, thanks guys. This has been a fun family activity for Monday night. Bye.

Family 2 (Control Condition).

Caregiver: We gonna pop some popcorn on the stove.

Child: I didn't know you could do it this way.

Caregiver: We usually do it in the microwave but they gave us this one for the stove.

Child: Does it taste the same?

Caregiver: I don't know. I guess we'll find out. Hand me the cup with the popcorn.

Child: It tells us what to do here.

Caregiver: Yeah, I see it.

Child: I'm gonna get my phone too.

Caregiver: Ok.

Child: How long is this gonna take?

Caregiver: Not long, it is already popping.

Child: Yeah, I hear it.

Caregiver: It says it is done when it slows down. You think it is ready?

Child: Yeah, I think so.

Caregiver: That is pretty good.

Child: I think I like it better than the microwave.

Our results provide three unique contributions to the literature. The first demonstrates that adding wh-questions to an everyday cooking activity was associated with more challenging family STEM talk than activities without wh-questions. Our simple intervention added three wh-questions to a recipe and asked families to discuss these questions as they made popcorn. Unsurprisingly, our results demonstrate that families naturally interact during cooking activities with or without prompts. Many families had rich conversations in which they discussed events like watching a movie or simply shared details of everyday life. The impact of the intervention was to add a slightly different focus to family conversations. As illustrated in the conversation from Family 2 above, conversations for families in the control group often centered around completing the task itself. This is not surprising, given that cooking is a structured activity that involves management of specific items in a specific order. In addition, the presence of high heat sources and potentially dangerous situations (e.g., hot oil) necessitates a degree of caution and caregiver supervision, given the participation of children. Notably, no significant differences occurred between groups on the quantity of non-STEM talk, providing additional evidence for baseline similarity between groups. This strengthens confidence in the conclusion that differences in family STEM talk between groups were related to the presence of wh-questions in the recipe. Extending previous research (Haden et al., 2014; Hanner et al., 2019; Leech et al., 2013), the presence of wh-questions increased the frequency of challenging STEM talk among our families defined as the use of STEM words, explanations and questions, and greater conversational elaboration. As illustrated in the conversation from family 1 above, families with wh-question prompts produced more utterances and words that are related to the prompts. For example, toward the end of the transcript, the caregiver asks "Why do you think that some of the kernels did not pop?" This question starts a chain of utterances related to and elaborating on this question. The utterances include STEM words, causal explanations, and elaborations. The initial wh-question prompted a rich, interactive conversation that engaged the caregiver and child in a discussion of STEM.

This effect was particularly evident in the productions of the children in these activities. Children in the experimental group produced more challenging STEM talk than did children in the control group, with more STEM words, explanations, and elaborations. The presence of these wh-questions highlighted interesting elements of this everyday activity and sparked curiosity. For example, the third prompt asking why some of the kernels did not pop led to several discussions about what causes popcorn to pop. Returning to the conversation of Family 1, the child makes two causal statements about how heat is related to popcorn popping, and her caregiver reinforces and extends this explanation. One clear way to illustrate the impact of the question prompts is that children in the experimental group produced an average of six times as many STEM words, asked five times as many STEM questions, and almost nine times as many explanations as children in the control group.

Challenging family talk is a powerful mechanism for promoting learning and cognitive development (Anderson et al., 2021). Specifically, challenging family talk (Anderson et al., 2021) supports elaborations (Haden et al., 2014; Marcus et al., 2017) and the construction of causal explanations (Booth et al., 2020; Letourneau et al., 2021). These relations were demonstrated in the correlational analyses in the results. Although causal direction cannot be determined from these analyses, they do suggest that the presence of wh-questions is associated with more elaborations and causal explanations in family talk.

Family talk included all of these elements, but their frequency was much higher for families in the experimental groups. For example, prompting conversations about noticing (e.g., *What looks different before and after the kernels pop?*) focuses attention on relevant phenomena and sets up further observation and explanation. The conversation from Family 1 includes multiple instances of noticing, which sets up observing and then explaining phenomena. It also provides additional evidence for the question-explanation-follow-up learning cycle (Kurkul & Corriveau, 2017). This "noticing first" pattern is foundational for STEM education as noted in the Next Generation Science Standards (NGSS Lead States, 2013).

We have provided evidence for the efficacy of a simple, low-cost, scalable intervention that has the potential for wide implementation. As noted in the introduction, family STEM talk is a rich mechanism for augmenting development by increasing the frequency of challenging family, particularly child, STEM talk as well as downstream benefits such as STEM interest, learning, and identity (Hurst, Polinsky, Haden, Levine, & Uttal, 2019). In addition, there is strong evidence from previous interventions that STEM talk is a malleable factor that can be increased by well-designed interventions such as creating engaging learning spaces that promote family talk (Hassinger-Das, Palti, et al., 2020), providing wh-question prompts in museum exhibits (Haden et al., 2014), or adding math question prompts to grocery store signage (Hanner et al., 2019). The project described in this paper took inspiration from these light interventions to create an intervention that was low cost, required no training or prior knowledge from participants, and provided minimal oversight during its use. Most important, the intervention had to produce a measurable change in family STEM talk. Our intervention fit the criteria outlined above in that it was low-cost (less than $1 per container of popcorn and oil, including the cost of the container), the instructions did not require any knowledge of the science of popcorn, the activity itself was a very simple cooking task, and the research team was not present during the activity itself. Importantly, nearly all of the families (31 of 32) in the experimental condition used the intervention with fidelity, as measured by asking at least 2 of the 3 wh-questions in their conversations. This high level of fidelity may have been due to the incentive ($25 gift card) or the simplicity and/or novelty of the activity.

Moreover, another unique contribution involved our recruitment technique and strengths-based approach to working with food-insecure families. Recall that the project was part of a larger outreach to food-insecure families during the COVID-19 pandemic. The popcorn kits were included in food kits distributed to several hundred families in the Cincinnati region. Our recruitment approach was designed to be respectful of the families in this community by providing materials and an opportunity to participate as part of a food distribution project. If families chose to participate, our approach was to provide prompts for questions that might add value to the conversations that were likely to take place during cooking. Building upon the strengths of family-centered meal time and cooking within this population, our intervention added prompts that augmented the sharing, particularly conversational sharing, that takes place around food spaces. Finally, our light intervention was designed so that no STEM knowledge was necessary to participate. The intervention included questions to promote information-seeking, rather than teaching (i.e., pedagogical questions; Yu, Bonawitz, & Shafto, 2019), which makes participation in the activity less dependent on the possession of specific knowledge.

As demonstrated in the data, the prompts leveraged existing knowledge, experience, and insights into the science of cooking (e.g., the properties of heat) that created engaging discussions. Families produced rich conversations that demonstrated curiosity, excitement about learning, and enjoyment in family engagement. These results suggest that in-home cooking activities may provide a promising avenue to reach families who may not otherwise be reached through traditional informal activities (e.g., museum memberships).

Limitations

The present study has several limitations. One is related to the recruitment of participants. As noted, hundreds of food kits were distributed, but only a small number of those who received these kits participated in the experiment. It is possible that there is a self-selection bias in the sample of those who were more experienced or comfortable with STEM content, although note that random assignment to group meant that the positive effects of the intervention are real but may not occur (or may even be larger) for other populations of participants. It is also evident that the relatively low percentage of families participating suggests that this method of recruitment may not be the most efficient. One anecdote from a family who did not participate indicated that they were unaware of the opportunity (this family did not notice the QR code). Future efforts might be more effective if materials were accompanied by clearer explanations for participation opportunities.

A second limitation is that we did not include a sample from a different SES to estimate the extent to which the results may generalize. Our intervention targeted a similar demographic as Hanner et al. (2019) and found similar results, but it is important to understand the extent to which this type of intervention is effective only within specific demographics, or if the effects are related to the type of task. For example, it is possible that conversations during cooking might be similar across demographic groups and that prompts might be more efficacious in such tasks compared to talk in other, less structured settings (e.g., grocery stores).

A third limitation is that there was no baseline data collected before the intervention to compare family STEM talk prior to the intervention. Although such data would have been informative, the intervention was designed to require minimal time and effort on the part of the participating families. Based on the suggestions of our community partner organizations, we designed the intervention so as not to require participation more than once. One goal for future research is to develop deeper relationships within this community that will allow for multiple opportunities that have value for the participants.

Finally, one possible limitation is that there was no measurement of the impact of the changes in family STEM talk over time or on other possible outcome variables (e.g., STEM interest). Although there is clear value in the evidence for increases in STEM talk, it is unclear if these increases are durable, or if this is an example of strictly situational interest (Renninger & Hidi, 2011) that will not provide a lasting benefit to families. Related to the point above, such data that would connect family STEM talk to other downstream outcomes would be useful, though are beyond the scope of the present study.

Implications and conclusions

Developmental implications

As outlined in the introduction, family talk is a mechanism that supports and augments not only child STEM talk but cognitive development (Anderson et al., 2021; Rowe et al., 2017). Our study adds to this body of literature by demonstrating that adding carefully targeted prompts for family talk to a familiar, everyday activity can increase family STEM talk. Family talk occurs within a social context that allows a child's individual knowledge to be shared and augmented by their interactions with others, notably trusted adults (Callanan & Jipson, 2001; Rogoff, 2003). Increasing the frequency of challenging family talk provides opportunities for children to acquire and increase vocabulary (Weisleder & Fernald, 2013). Family talk that includes more complex vocabulary, opportunities for explanations, and prompts for elaborations provides positive challenges that promote cognitive development, particularly when it occurs within supportive social contexts (Rogoff, 2003).

Challenging family STEM talk, like that demonstrated in families in the experimental group, supports children's cognitive development. Family STEM talk helps children acquire STEM words (Leyva et al., 2021). Family talk that includes prompts for explanations (e.g., wh-questions) helps children generate causal explanations, which help children understand STEM phenomenon (Legare et al., 2017). Finally, talk that involves elaborations, such as follow-up questions and statements with additional information, provides support for child talk and cognitive development (Fivush et al., 2006; Melzi et al., 2011). Elaborations allow children to acquire new knowledge and extend and repair existing knowledge (Roscoe & Chi, 2008). Family STEM talk also helps children develop positive STEM identities (Bonnette et al., 2019; Dou & Cian, 2021). Our results demonstrated that children's STEM talk increased across all of these dimensions, suggesting the potential for broader cognitive impacts.

Applied implications

Our results establish that adding wh-question prompts to a recipe significantly increased the quality of family STEM talk. This project demonstrates the efficacy of a simple, scalable intervention, or light intervention, that is brief, low-cost, and requires no specialized STEM knowledge to implement. Our light intervention provided an opportunity for families to engage in guided learning (Braham, Libertus, & McCrink, 2018), which moves families toward shared information-seeking based on curiosity (Jirout & Klahr, 2012) and shared learning goals (Weisberg, Kittredge, Hirsh-Pasek, Golinkoff, & Klahr, 2015). This practice differs from pedagogical learning in which caregivers ask questions about which they know the answers in an effort to teach, rather than guiding questions that guide exploration (Yu et al., 2018). Although pedagogical questions do promote learning (Daubert et al., 2020), this approach may be avoided by caregivers who believe they lack STEM knowledge or a strong STEM identity (Dou, Hazari, Dabney, Sonnert, & Sadler, 2019). Thus, creating activities in which STEM knowledge is unnecessary might widen participation for children and caregivers to engage in STEM learning.

Another implication of this project is for recruitment and engagement with families experiencing food insecurity. Little is known about child development within food-insecure families, particularly in relation to academic and STEM engagement (Higashi et al., 2017; Rosemond et al., 2019). Our novel method of recruitment involved minimal contact during a pandemic and provided basic supplies to all potential participants. The approach of bundling recruitment opportunities with other outreach efforts is economical and has the potential to increase buy-in from community organizations and the populations they serve. In addition, the decision to create a strengths-based approach for promoting family talk was based on the idea that cooking and meal-sharing is an important part of family time in food-insecure families (Leyva et al., 2021; Rosemond et al., 2019). A final application is that the incentive was likely helpful in recruiting and obtaining high fidelity. Researchers must be cognizant of the demands placed on potential participants so that we can value their time and effort appropriately.

In conclusion, family talk is an important mechanism for increasing children's STEM talk as well as their social and cognitive development through positive, cognitive challenges within supportive, social contexts. Our results suggest that light interventions, such as adding wh-questions to a recipe, help increase the amount of challenging family STEM talk, particularly child STEM talk, that includes more varied STEM vocabulary, more STEM questions and explanations, and more detailed and elaborative conversations about STEM.

Author statement

The research project was approved by the Kent State University IRB and the research was conducted in accordance with APA ethical standards for research with human subjects. This material is based upon work supported by the National Science Foundation under Grant Number 1906706. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. All data will be made available upon reasonable request.

Reflexivity statement

The framing of this research is grounded in a strengths-based approach and challenges negative stereotypes of historically excluded, oppressed, or vulnerable groups by demonstrating high levels of STEM curiosity and engagement in food insecure families. Our sample was drawn from food-insecure families in the Cincinnati, OH region and is 53% white, 37% Black/African-American, and approximately 10% Asian-American/Pacific Islander. It is our opinion that our research and findings should not harm historically marginalized groups and in fact provides evidence of considerable strengths within this community.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appdev.2023.101581.

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