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# Relations between parent–child interaction and children's engagement and learning at a museum exhibit about electric circuits

David M. Sobel[1] | Susan M. Letourneau[2] | Cristine H. Legare[3] | Maureen Callanan[4]

[1]Brown University, Providence, RI, USA

[2]New York Hall of Science, New York, NY, USA

[3]The University of Texas at Austin, Austin, TX, USA

[4]University of California, Santa Cruz, Santa Cruz, CA, USA

**Correspondence**
David M. Sobel, Department of Cognitive, Linguistics and Psychological Sciences, Box 1821, Providence, RI 02912, USA.
Email: dave_sobel@brown.edu

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## Abstract

Play is critical for children's learning, but there is significant disagreement over whether and how parents should guide children's play. The objective of the current study was to examine how parent–child interaction affected children's engagement and problem-solving behaviors when challenged with similar tasks. Parents and 4- to 7-year-old children in the U.S. ($N$ = 111 dyads) played together at an interactive electric circuit exhibit in a children's museum. We examined how parents and children set and accomplished goals while playing with the exhibit materials. Children then participated in a set of challenges that involved completing increasingly difficult circuits. Children whose parents set goals for their interactions showed less engagement with the challenge task (choosing to attempt fewer challenges), and children whose parents were more active in completing the circuits while families played with the exhibit subsequently completed fewer challenges on their own. We discuss these results in light of broader findings on the role of parent–child interaction in museum settings.

**KEYWORDS**
causal learning, parent–child interaction, STEM engagement, STEM learning

## 1 | INTRODUCTION

Collaborative, playful interaction is an essential part of children's learning experiences (Weisberg et al., 2014). Children's museums are designed to provide opportunities for both children's independent exploration and parent–child interaction (Callanan & Jipson, 2001; Gaskins, 2008; Van Schijndel et al., 2010). With more than 40 million visitors each year to children's museums in the U.S. (Association of Children's Museum, 2017), it is critical to document and understand how interactions in such informal learning environments can support children's learning (Luke & Garvin, 2014).

When parents and children interact at museum exhibits, parents provide explanations, guide children's attention, help them interpret evidence, and connect their observations with prior experiences (Benjamin et al., 2010; Borun et al., 1996; Callanan et al., 2020; Crowley et al., 2001; Puchner et al., 2001; Van Schijndel & Raijmakers, 2016). These studies demonstrate that the ways parents and children interact at exhibits affect what children learn from these experiences (see also Braham et al., 2018; Perez & McCrink, 2019). More generally, the literature on parental "scaffolding" (Wood et al., 1976, p. 90) suggests that parents can teach children to solve complex problems by controlling elements of the task that children might not be able to do for themselves. Wood et al. (1976) argue that parents contingently act in response to what children understand about the interaction. This may allow children to master the elements of the task that they do understand, while also giving them exposure to the other more complex facets of the task.

Research on scaffolding originally described one-on-one tutoring in a problem-solving environment (e.g., Conner & Cross, 2003; Meins, 1997; Pratt et al., 1988; Wood & Middleton, 1975; see Mermelshtine, 2017, for a review). Scaffolding can also occur in natural, everyday interaction across numerous domains and

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environments (e.g., Bigelow et al., 2004; Dieterich et al., 2006; Tamis-LeMonda et al., 2014). This is similar to parent–child interaction in museum settings, where there might not be clear intentions for parents to teach their children or structured problems to solve. Many activities in museum settings are designed to be open-ended; families can set their own goals as they interact with exhibit components, tailoring them to children's interests and abilities.

The core question behind our investigation was how children's interactions with their parents while playing at a museum exhibit affected their engagement and problem-solving behaviors when challenged with the same materials. While children's success in problem-solving has been the hallmark of many previous investigations on parent–child interaction, fewer studies have examined children's subsequent engagement with the task (see Bae et al., 2014; Medina & Sobel, 2020; Rhodes et al., 2019). Because research on play in children's museums has often focused on children's engagement with exhibits (e.g., Chermayeff et al., 2001), documenting how parents can support such engagement is as fundamental as documenting children's success on problem-solving tasks.

We asked parents and children to play together at an open-ended electric circuit exhibit and then presented children with a set of progressively more difficult electric circuit construction challenges in which their participation in each challenge was optional. We wanted to determine if aspects of parents' and children's play predicted how many challenges children chose to engage in on their own, and whether they solved these challenges without assistance. Numerous investigations of parental scaffolding have also found individual differences based on parental education level and other variables (e.g., Bae et al., 2014; Carr & Pike, 2012; Mermelshtine & Barnes, 2016). Thus, we also considered several demographic factors in our analysis.

We focused on several facets of parent–child interaction. The first facet was *goal-setting*: Who set goals during the interaction? We predicted that if parents were directive and set goals for children, children will have less control over the interaction and therefore will be less engaged by the activity. We used the parent–child interaction style coding scheme initially described by Fung and Callanan (2013), more recently used by Callanan et al. (2020) and Medina and Sobel (2020). Medina and Sobel (2020), for example, presented parents and children with a problem-solving measure, in which children had to learn a set of abstract rules about a causal system through free play. They categorized interactions as parent-directed (in which parents set more goals than children and were directive while accomplishing those goals), jointly-directed (in which parents and children jointly set goals, and were collaborative in accomplishing them), or child-directed (in which children set more goals and took more control of the interaction, with parents being supportive, but hands-off). They found that children in the jointly-directed dyads were more engaged with the learning activity than children in the other two groups.

The second facet of parent–child interaction we measured was *goal-completion*: Who in the dyad generated actions to complete circuits during free play? Actions generated on the part of parents and children speak to children's agency and autonomy. Because we used an exhibit designed for children to manipulate, if parents act more during while playing with their children, children might believe they have less autonomy. This might make children less likely to believe they can solve the problem on their own. We predicted that when parents completed goals for children at the exhibit, children might be less able to accomplish those goals on their own. While there can be many goals during free play, we planned to ask children to build a particular set of electric circuits. As such, we looked at whether and (more importantly) how dyads built the challenge circuits during the free play, and the extent to which parental or child action prior to completing those circuits predicted children's ability to construct the circuit on their own.

We also examined effects on children's engagement independently from their performance on the challenges. Doan et al. (2020) recently showed that successful performance on a task makes children more engaged and more willing to explore novel tasks of the same type in the future. Our analyses controlled for this factor by examining how many challenges children chose to attempt, as well as the proportion of those they completed on their own. Similarly, because we expected that parents who set more goals might also engage in more actions than their children at the exhibit, we wanted to determine whether the role of parental action was independent of the parent–child interaction style. Finally, we expected that as children got older, they would bring more knowledge and potentially be more engaged in the activity. As such, we investigated not only whether older children were more engaged and knowledgeable about electric circuit construction, but also whether other factors uniquely predicted children's engagement and performance beyond the role of age.

A third facet of parent–child interaction we examined was the language children heard while playing with their parents. Various studies document relations between parents' causal language and children's learning outcomes (e.g., Chandler-Campbell et al., 2020;

**Research Highlights**

- We examined relations between parent–child interaction at a museum exhibit and children's subsequent engagement with and completion of related individual challenges at that exhibit.
- When parents set more goals relative to their children, children showed less engagement with the challenges, controlling for children's age.
- When parents engaged in more actions prior to completing electric circuits, children completed fewer electric circuit challenges on their own, controlling for children's age.
- Quality and not quantity of parental interaction during play was related to children's engagement and learning with a STEM activity.

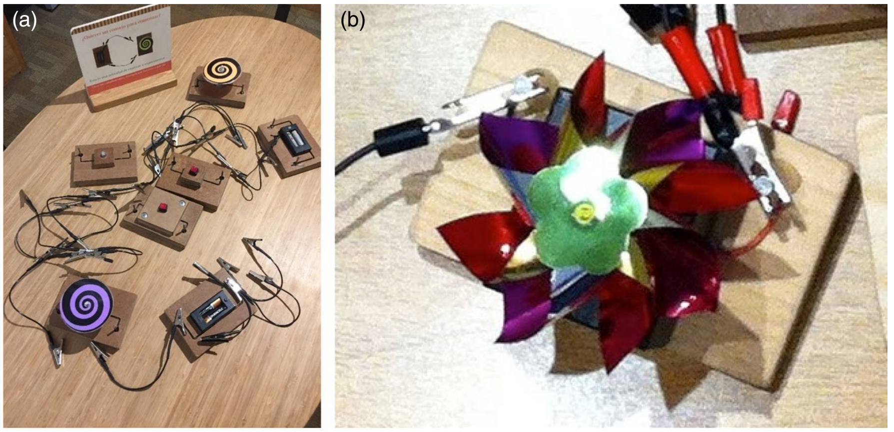


FIGURE 1 (a,b) View of the circuit exhibit used in the study. The exhibit had eight circuit components (two buttons, two batteries, two spinning motors, and two LED light bulbs) as well as set of alligator clips to connect the components. The exhibit also had a label in English and Spanish that showed how two components (a battery and a motor) could be connected with the alligator clips (a). (b) The pinwheel used in the challenges

Crowley et al., 2001; Philips & Tolmie, 2007; Tare et al., 2011). We examined whether the causal language parents generated during their interactions was related to children's ability to solve the challenges when tested on their own. Similarly, numerous studies have documented effects of praise—particularly praise of effort—on children's engagement (e.g., Gunderson et al., 2013; Mueller & Dweck, 1998). We also examined whether the frequency with which parents generated this kind of praise while interacting with their child was related to children's subsequent engagement with the challenges.

Thus, our study is organized around three research questions. These questions attempt to document how the quality of parent–child interaction relates to children's engagement and learning. First, how do goal-setting and goal-completion during parent–child interactions relate to children's participation in the challenges (our measure of engagement) and performance on the challenges (our measure of learning)? Second, does parents' generation of causal language or types of praise relate to children's learning or engagement? Third, do parental demographics relate to our measures of goal-setting, goal-completion, children's engagement, or learning?

# 2 | METHOD

## 2.1 | Participants

Our sample consisted of one hundred-eleven 4- to 7-year-olds ($M_{age}$ = 71.50 months, SD = 13.44, range = 49.30–95.60, 52 girls and 59 boys). This sample size was determined by a power analysis following the effect size calculated from the analysis of goal-setting on children's engagement conducted by Medina and Sobel (2020), assuming $\alpha = 0.05$ and $\beta = 0.80$ and an odds ratio of 1.83 (the effect size of their finding using the same kind of ordinal logistic regression).[1] This sample size was also sufficiently large to assume this level of power for the other analyses reported below. Children were recruited and tested at Providence Children's Museum during family visits to the museum. Children were tested with at least one parent or legal guardian (22 with a male parent, 89 with a female parent). Further demographic information about parents and children is provided in Supporting Information.

## 2.2 | Materials

The electric circuit blocks used in the free play portion of the procedure were taken from an existing exhibit at the museum. The blocks presented to families included two blocks with bidirectional LED lights that would activate in either red or green (depending on the direction of the connection), two blocks with motorized spirals (one orange and one purple, which could spin in either direction, dependent on the construction of the circuit), two battery blocks (with windows revealing AA batteries), and two button blocks. Also present on the table at the start of the procedure were approximately 30 alligator clip wires and a double-sided sign, which was normally part of the circuit block exhibit (see Figure 1a). The sign showed a photo of a disconnected electric circuit made from one battery block, one motor block, and two wires not fully connected, depicted from above. The picture was present on both sides, with English words on one side and Spanish on the other, which read, "Need a hint to get started? This activity is about exploring and experimenting. It's tricky. Figure out what works and what doesn't." A circuit block of a motorized green pinwheel was used in the challenges phase, but not the free-play portion of the procedure. The pinwheel block (Figure 1b) was similar to the spirals, but instead of a flat laminated spiral, was a three-dimensional pinwheel that could also spin in either direction.

## 2.3 | Procedure

The study procedures were approved under Brown University IRB protocol #1307000890, *Explaining, Exploring and Scientific Reasoning* *in Museum Settings*. Families were asked to sit at the exhibit table with the exhibit materials, including the eight circuit blocks, alligator clips, and sign. At the start of the procedure, one battery block and one effect block (either a spinner or a light) had an alligator clip attached to it, as an example of how the clips attached to the blocks. No two circuit blocks were connected to one another at the start. This parallels the way in which museum staff typically set up the exhibit to invite exploration by families.

For the first *free play* part of the procedure, the researcher instructed groups to play with the circuit blocks however they liked, letting them know that they would have up to 15 min to play with the blocks. Researchers started the timer when the participating child approached the table after consent was obtained. Groups were allowed to stop playing at any point they wished, but if they did not do so spontaneously, groups were given a 5-min and a 2-min warning before moving on to the next part of the procedure. Because families visited the museum as a group, siblings and other members of the family group were also allowed to play with the circuit blocks at the same time, but only one child per family participated in the challenges (determined randomly, prior to the start of the study if two children met other inclusion criteria).

After the group was finished playing, the researcher asked just the participating child to stay at the table and started the *Challenge Phase*. The researcher disconnected all of the alligator clips from the circuit blocks on the table. She told the participating child, "Now that you've played with these for a little while, I have some challenges for you to try." The parent was given the demographic information survey as well as a set of other questionnaires to fill out while the researcher interacted with the child. For any other sibling or child in the group, the researcher explained that this part of the game was only for the child participating in the study, and these children were allowed to sit nearby and watch the participating child without helping, or play with other toys present in the space.

Participating children were then given a series of eight challenges, described in Table 1. Challenges were designed to be increasingly difficult for children of this age group, and the order was determined through pilot testing. After completing each challenge, children were asked if they wanted to try another challenge, or if they wanted to stop the task.

For each challenge, the researcher would first pose the challenge (e.g., "Can you show me how to make the light turn on?") and would then wait for children to attempt to connect circuit blocks together. If children were not sure what to do or tried something that did not work (i.e., connected the circuit blocks incorrectly and then stopped), they were given increasingly informative prompts until they were able to complete the challenge. First, the researcher encouraged children to continue working by saying, "It's tricky. Keep trying and see if you can figure it out." If the child stopped and asked for help, or tried the same thing, which continued not to work, the researcher provided further encouragement by saying, "try something different" or "what else can you try?" If the child stopped again, the researcher would ask whether the child wanted a hint (exact language for the hints provided in Table 1). At this point, children would be provided with a hint if they wanted one, but the researcher would not interact with the circuit blocks or connect them. Finally, if children were still stuck, the researcher would ask whether they wanted to know the solution, and if so, the researcher would give them direct instruction as to how to solve the challenge. This support was provided so that all children were encouraged to solve the challenges on their own (providing a measure of learning), but would all ultimately be able to complete each challenge before deciding whether to attempt another challenge (providing a measure of engagement with the task, regardless of performance). Moreover the support used to administer the challenges mimicked the language museum facilitators would use while helping children explore the exhibit on the museum floor, so the use of these supports allows us to test children's engagement and performance on the challenges in a naturalistic way.

Both the free play and the challenge phases were video recorded for subsequent analysis. The free play phase was also transcribed, so that coders could base their judgments on both the video and a transcription of the language generated by parents and children. Details about the transcription process are provided in Supporting Information.

## 2.4 | Coding

### 2.4.1 | Engagement and performance on the challenges

At the start of the challenges, children had already played with the circuit blocks for up to 15 min and had the option to stop the challenges at any time. We therefore considered the number of challenges children chose to try as a measure of their engagement. We considered the number of challenges that children were able to complete on their own (without any hints or instruction from the experimenter), out of the total number they attempted, as a measure of what they learned about the electric circuits.

### 2.4.2 | Goal setting

To measure goal setting, we examined two facets of the parent–child interaction. First, we defined three interaction styles that holistically described how caregivers and children played at the exhibit, based on a coding scheme described by Fung and Callanan (2013; see also Callanan et al., 2020; Medina & Sobel, 2020). Coders looked at the whole of the interaction and judged who set more goals at the exhibit—the parent, the child, or both jointly. Coders were asked to consider only the actions of the parent and the participating child (referred to as "dyads" below) in making these judgments.

We coded dyads into one of three groups: (1) *Parent-directed*: Parents both set goals for the interaction and either engaged in actions themselves or instructed the child to engage in specific actions to build particular electric circuits. (2) *Jointly-directed*: Parents

**TABLE 1** List of eight challenges, hints, and solutions used in the script of the study

| Challenge | Hint given (if necessary) | Solution given (if necessary) |
|---|---|---|
| (1) *Nearly complete circuit*: Show a circuit with LED light, almost complete (Battery block has two alligator clips attached, LED has one side attached but not the other): "Can you show me how to make the light turn on?" | "What do you need to connect?" | "Try connecting it to the light" [Show exactly where to connect alligator clip] |
| (2) *Circuit with a new effect, from scratch*: The LED Circuit used in Challenge 1 is pushed to the side of the table. Bring out the other battery block, extra alligator clips, and mechanical pinwheel effect block (not used during free play): "Now, can you make this one go?" | "What parts do you need to make it work?" or "is there a part missing?" | "Try connecting it to the battery on both sides." [Show exactly where to connect alligator clips] |
| (3) *Circuit with on-button*: Once child has circuit with pinwheel going: "Great! OK, let's make it stop again." [Disconnect pinwheel from battery on both sides so it stops. Give child a button block] "Now, can you use this button to make it go?" | "What if you connect the pieces in a circle?" or "Can you put the button in between the battery and the pinwheel?" | "Try connecting this side of the battery to the button and that side to the pinwheel. Then connect the button and the pinwheel together." (showing children where to connect each clip) |
| (4) *Circuit with two effects*: Once child has a circuit with a pinwheel and button: "Let's take away the button and start with the pinwheel spinning like before." [Reconnect battery & pinwheel; Give child the other LED block.] "Now, can you make the pinwheel and the light go at the same time? (using any of the pieces on the table)" | "Are both pieces connected to the battery?" | Try connecting both sides of the pinwheel to the battery and both sides of the light to the battery.[Show where to connect each clip] |
| (5) Directional effects: [Disconnect existing circuits. Connect just the LED and battery as it was in the beginning, put pinwheel off to the side.] "Look, this light is green/orange. Can you make the light turn on in [the other color]?" | "What if you switch which sides are connected?" | "Try connecting this side of the battery to that side of the light." [Show exactly where to connect each clip.] |
| (6) *Directional effects, transferring strategies*: [Push the circuit from challenge 5 off to the side, still in view. Bring out the pinwheel, a second battery, alligator clip wires.] "Let's connect this one again like you did before." [Letting child make the same pinwheel circuit again from Challenge 2.] "Look, it's spinning this way"—indicate clockwise or counterclockwise. "Can you make it spin the other way?" | "What if you switch which sides are connected?" | "Try connecting this side of the battery to that side of the light." [Show exactly where to connect each clip.] |
| (7) *Circuit with off-button*: Once child has a circuit with pinwheel spinning again: "OK, now, can you use a button to make the pinwheel stop spinning?" | "What if you connect the three pieces in one line? | "Try connecting the battery to the motor on both sides and then connect the battery to the button on both sides." [Show where to connect each clip.] |
| (8) *Circuit with off-button, transferring strategies*: [Bring back the circuit with the LED light from Challenge 5.] "Now can you use a button to make the light turn off?" | "What if you connect the three pieces in one line? | "Try connecting the battery to the motor on both sides and then connect the battery to the button on both sides." [Show where to connect each clip.] |

let children set goals and facilitated children's exploration by asking questions and making suggestions to help children accomplish their goals. (3) *Child-directed*: Children both set goals and accomplished goals for themselves; parents were more passive during the interaction and allowed children to explore freely. Supporting Information provides further details on this coding. Two undergraduate research assistants, different from the research assistants who coded any of the language utterances and blind to the hypotheses of the experiment, coded a new randomly selected 20% of the sample. Agreement was 88%, $\kappa = 0.82$. Disagreements were resolved through discussion with the first author (who, along with the research assistants, was blind to children's performance on the outcome measures when resolving these disagreements).

Independent of this coding, we coded the number of goal statements generated by parents and children. Goal statements implied that the child or parent stated they were working towards a desired outcome regarding the circuit blocks. Goal statements were marked by the presence of particular verb phrases that directed actions towards the circuit blocks: *going to*, *want to*, *trying to*, *need to*, *have to*, *got to* (or *gotta do*), *will do*, *let's* or the question "What if we <verb denoting action on the circuit blocks>?" Goal statements did not include imperatives ("Make the light turn on." or "Now try it."). Utterances with one of those verb phrases that were not about the circuit blocks were also not coded as goal statements (e.g., "I want to go play with the water now." "Let's try to share with your brother." "Let's go get a snack."). Two different undergraduate research assistants, blind to the hypotheses of the experiment, coded a randomly selected 20% of the sample for the goal statements. Agreement was 97%, $\kappa = 0.74$. Disagreements were resolved through discussion with the second author. The remaining 80% were then coded by one of these two research assistants.

#### 2.4.3 | Goal completion

Goal completion was coded based on whether children and parents built any of the eight circuits later used in the challenges. We counted the number of such circuits built during the free play, as well as who was engaging in actions in the 30-s time window prior to and after the completion of those circuits. Because of the nature of the exhibit, there were only a small number of actions that could be performed (connecting or disconnecting a wire to a circuit block, and pressing buttons). The number of these actions was counted. The details of this coding are given in Supporting Information. Actions in the 30 s prior to completing the circuit provided a measure of how active parents and children were during the completion of the goal, and actions in the 30 s immediately afterward served as a control measure for how active parents and children were more generally. Two undergraduate research assistants, blind to the hypotheses of the experiment, coded 20% of the data for reliability. Agreement was 94% ($\kappa = 0.91$). Disagreements were resolved through discussion with the second author. The remaining 80% of the data were then coded by one of these two research assistants.

#### 2.4.4 | Other language coding

In addition to coding all parent and child utterances for goals, we also conducted a language analysis on all of the parent and child utterances. Our coding paralleled a coding scheme used by Callanan et al. (2020) for coding parents' and children's utterances at a STEM exhibit in a children's museum. This system is described in detail in Supporting Information. Generally construed, we classified utterances made by both parents and children into one of three broader categories: *causal language*, *descriptions about the exhibit or actions*, and *other utterances*, although each of these broad categories had numerous subcategories (described in Supporting Information). The same two undergraduate research assistants who coded the goal statements coded these data (independent of their coding of the goal statements). They each coded 20% of the data. Agreement on these codes was 84% ($\kappa = 0.70$). Disagreements were resolved through discussion with the first and second authors (who were blind to performance on the outcome measures). These two research assistants then each coded the remainder of the dataset individually.

We also singled out one other type of utterance—praise and encouragement generated by parents—in a separate language analysis. We used the coding system used by Gunderson et al. (2013). Here, we divided praise utterances into process (about the effort), person (about the child), and other (non-specific praise like "good job"). Two research assistants (who had not coded any other aspect of these data previously) coded these data. Agreement was 93%, $\kappa = 0.86$.

## 3 | RESULTS

We first examine the role of goal setting on children's engagement and then on performance on the challenges. Then we examine the role of goal completion on engagement and performance. Next, we consider the other language factors that we coded, and finally, the role of demographic factors.

Table 2 shows the results of our coding for the three parent–child interaction styles as well as analyses of differences among the three groups. Nonparametric analyses were used because not all distributions were Gaussian. As can be seen from Table 2, overall, children participated in an average of 6.05 out of the 8 possible challenges, and children solved 73% of the challenges they engaged in without hints or direct instruction.

### 3.1 | Does goal-setting predict children's engagement?

We considered parent–child interaction style as a holistic indicator of how goals were set during the dyad's entire interaction with the exhibit. We also examined the number of goal-setting utterances generated by parents and children as a particular fine-grained measure of how frequently parents and children set goals aloud. We asked whether either of these measures related to the number of challenges children engaged in during the challenge phase.

There was a significant difference among the three parent–child interaction styles regarding the number of challenges children participated in, Kruskal–Wallis $\chi^2(2) = 15.03$, $p = 0.001$. Simple effect analyses performed with a Dunn–Bonferroni correction showed that the children in the parent-directed group engaged in fewer challenges during the challenge phase than children in the child-directed group, $p = 0.006$, or children in the jointly-directed group, $p = 0.001$.

We conducted a set of hierarchical regressions assuming an ordinal response for the number of challenges children participated in during the challenge phase as a dependent variable. Because children's age significantly differed among the three parent–child interaction groups (see Table 2), the first model contained children's age (in months), and the proportion of challenges children responded to correctly without hints or instruction as independent variables. The second model then added parent–child interaction style. The third model added all the interactions among these variables. The difference between Model 1 and Model 2 (as measured by −2 log likelihood) showed that adding the measure of parent–child interaction explained significantly more variance in the model, $\chi^2(2) = 7.39$, $p = 0.02$. The difference between Model 2 and Model 3 showed that adding the interactions among age, proportion correct, and PCI style resulted in a non-significant trend, $\chi^2(7) = 13.70$, $p = 0.06$. However, given that Model 3 was significantly different from an intercept only model, $\chi^2(11) = 75.54$, $p < 0.001$, we will report the results of that model.

In Model 3, there was a significant positive effect of age, B = 0.50, SE = 0.15, 95% CI [0.21, 0.79], Wald $\chi^2(1) = 11.22$, $p = 0.001$, and a significant positive effect of the proportion of challenges children responded to correctly without hints or instruction, B = 44.71, SE = 13.40, 95% CI [18.45, 70.96], Wald $\chi^2(1) = 11.14$, $p = 0.001$. The overall effect of parent–child interaction style was significant, Wald $\chi^2(2) = 7.76$, $p = 0.02$. There was a significant difference between the parent-directed and child-directed groups, B = −0.58, SE = 0.21, 95% CI [−0.99 −0.16], Wald $\chi^2(1) = 7.29$, $p = 0.007$, and a marginally significant difference between the parent-directed and joint-directed groups, B = −0.36, SE = 0.20, 95% CI [−0.75, −0.03], Wald $\chi^2(1) = 3.35$, $p = 0.06$. Children in parent-directed dyads attempted significantly fewer challenges than those in child-directed dyads and jointly-directed dyads, but this latter difference did not reach statistical significance.

The significant interactions can help explain how the importance of parent–child interaction style changed with age and with success on the challenges. The interactions between parent–child interaction style and age, and between parent–child interaction style and proportion correct were significant, Wald $\chi^2(2) = 8.22$ and 6.42, $p = 0.02$ and 0.04. These interactions must be interpreted within a significant three-way interaction between age, proportion of challenges completed, and parent–child interaction style, Wald $\chi^2(2) = 7.63$, $p = 0.02$.

To appreciate the three-way interaction, we examined the number of challenges children attempted across parent–child interaction styles, looking at relations with age and with the proportion of challenges children solved on their own. For the jointly-directed and child-directed groups, as children got older, and as they solved more challenges on their own, they were likely to participate in more challenges, all $r_s$-values > 0.41, all $p$-values < 0.02. Children in these two groups, however, showed a different pattern of engagement than children in the parent-directed group, B = 0.76, SE = 0.28, 95% CI [0.20, 1.32], Wald $\chi^2(1) = 7.14$, $p = 0.008$, comparing parent-directed and child-directed groups, and B = 0.50, SE = 0.26, 95% CI [−0.01, 1.01], Wald $\chi^2(1) = 3.64$, $p = 0.05$, comparing parent-directed and jointly-directed groups. The younger children (based on a median split) in the parent-directed group showed a similar positive relation between the proportion of challenges they solved on their own and the number of challenges they engaged in, $r_s(17) = 0.80$, $p < 0.001$. The older children in this group showed a non-significant negative correlation, $r_s(16) = -0.23$, $p = 0.37$. This was unlike performance in either of the other groups; as children in parent-directed dyads got older, they participated in fewer challenges as their success on the challenges increased.

The analyses presented so far focus on parent–child interaction style. We also analyzed the number of goal statements generated by parents and children during their free play. Inspection of Table 2 reveals no difference among the three parent–child interaction groups in the percentage of goal-setting utterances generated by either parents or children. The percentage of goal-setting utterances generated by parents did not correlate with the number of challenges children participated in: $r_s(108) = -0.01$, $p = 0.95$; for children's utterances, this correlation was a non-significant trend, $r_s(107) = 0.17$, $p = 0.08$.

Finally, the way we structured the challenge procedure with linguistic supports (e.g., first offering open-ended encouragement, then hints, then direct instruction) was designed to replicate the types of scaffolding children would receive from a museum facilitator. However, it potentially created a dynamic where children knew they could get input on subsequent challenges, or signaled to children that they should stop their performance once they had to ask for help. Ninety-three of the 111 participants were given hints or instruction at least once during the challenge phase.

For these 93 children, 34% of the challenges they participated in occurred after the challenge where they first received hints or instruction, meaning that children did not immediately stop once they needed hints or help. The distribution, however, was not uniform among the parent–child interaction styles, (22% for the parent-directive group; 38% for the jointly-directed group; 43% for the child-directed group). A generalized linear model on this proportion with age and PCI style as dependent measures revealed a main effect of age, Wald $\chi^2(1) = 12.18$, $p < 0.001$ as well as a main effect of parent–child interaction style, Wald $\chi^2(2) = 5.93$, $p = 0.05$, with the proportion of the joint-directed and child-directed groups being higher than the parent-directed group, B = 0.62 and 0.57, SE = 0.28 and 0.28, 95% CI [0.06, 1.17] and [0.03, 1.13]. Wald $\chi^2(1) = 4.67$ and 4.33, $p = 0.03$ and 0.04. Children in the parent-directed group engaged in fewer challenges after they received hints or instructions, compared to the other two groups, again controlling for age.

## 3.2 | Does goal-setting predict children's performance on the challenges?

To consider whether parent–child interaction style and the percentage of goal-setting utterances generated by parents and children affected how many challenges children solved, we constructed a set of ordinal regression analyses on the proportion of challenges children solved without hints or instruction, looking at age, parent–child interaction style, and the number of challenges children participated in, as independent variables, building the same set of models as before. Model 1 (with children's age and the number of challenges they participated in as independent variables) was significant, $\chi^2(2) = 47.50$, $p < 0.001$. Model 2, which included parent–child interaction style, was not a better fit than the first, $\chi^2(2) = 0.36$, $p = 0.84$.[2] In Model 1, age was a significant predictor of children's successfully completing a higher proportion of challenges, B = 0.04, SE = 0.01, 95% CI [0.01, 0.07], Wald $\chi^2(1) = 7.10$, $p = 0.008$ as was the number of challenges children engaged in, B = 0.48, SE = 0.11, 95% CI [0.27, 0.68], Wald $\chi^2(1) = 20.40$, $p < 0.001$. Taken with the results from the previous section, these analyses suggest that children's engagement with the challenges is related to what they learn from the experience, and that parent–child interaction style uniquely predicted children's engagement. However, parent–child interaction was not related to children's performance on the challenges.

**TABLE 2** Age statistics and raw data on free play and challenges across parent–child interaction styles

| | Parent directed ($N$ = 37) | Jointly directed ($N$ = 39) | Child directed ($N$ = 35) | Difference among groups |
|---|---|---|---|---|
| Children's age (in months) | 65.50 (11.40) | 74.78 (13.19) | 74.18 (12.96) | Kruskal–Wallis $\chi^2(2) = 11.48$ $p = 0.003$ |
| Performance on challenges | | | | |
| Highest challenge attempted (out of 8) (measure of engagement) | 5.05 (2.07) | 6.62 (1.82) | 6.49 (1.72) | Kruskal–Wallis $\chi^2(2) = 15.03$ $p = 0.001$ |
| % of Challenges participated in solved without hints of instruction (measure of performance) | 65.92 (20.46) | 77.52 (16.54) | 74.69 (16.36) | Kruskal–Wallis $\chi^2(2) = 8.71$ $p = 0.01$ |
| Language during free play | | | | |
| % of utterances coded as goal oriented generated by parent | 8.26 (5.63) | 8.29 (8.19) | 7.37 (10.59) | Kruskal–Wallis $\chi^2(2) = 4.61$ $p = 0.10$ |
| % of utterances coded as goal oriented generated by child | 8.64 (8.25) | 11.51 (11.26) | 14.93 (18.32) | Kruskal–Wallis $\chi^2(2) = 1.42$ $p = 0.49$ |
| % of utterances coded as causal generated by parent | 4.80 (4.62) | 7.70 (6.44) | 4.99 (5.79) | Kruskal–Wallis $\chi^2(2) = 5.78$ $p = 0.06$ |
| % of utterances coded as causal generated by child | 3.94 (5.96) | 6.87 (8.93) | 3.85 (6.54) | Kruskal–Wallis $\chi^2(2) = 5.19$ $p = 0.08$ |
| % of utterances coded as process praise generated by parent | 0.68 (1.60) | 1.54 (3.21) | 1.16 (2.61) | Kruskal–Wallis $\chi^2(2) = 1.15$ $p = 0.56$ |
| % of utterances coded as person praise generated by parent | 0.14 (0.61) | 0.23 (0.71) | 0.38 (1.71) | Kruskal–Wallis $\chi^2(2) = 0.41$ $p = 0.82$ |
| % of utterances coded as other praise generated by parent | 4.53 (5.37) | 4.09 (4.75) | 6.75 (9.00) | Kruskal–Wallis $\chi^2(2) = 0.90$ $p = 0.64$ |
| Exploration during free play | | | | |
| Total challenge circuits constructed during free play (out of 8) | 3.43 (1.41) | 3.21 (1.76) | 3.03 (1.58) | Kruskal–Wallis $\chi^2(2) = 1.50$ $p = 0.47$ |
| Mean number of actions—parent 30 s before circuit completion | 4.29 (3.57) | 0.86 (1.84) | 1.82 (2.36) | Wald $\chi^2(2) = 94.44$ $p < 0.001$ |
| Mean number of actions—child 30 s before circuit completion | 2.70 (2.52) | 3.77 (3.09) | 4.05 (3.11) | Wald $\chi^2(2) = 10.17$ $p = 0.006$ |
| Mean number of actions—parent 30 s after circuit completion | 3.55 (4.17) | 0.56 (1.38) | 1.44 (2.19) | Wald $\chi^2(2) = 36.65$ $p < 0.001$ |
| Mean number of actions—child 30 s after circuit completion | 2.95 (2.85) | 4.98 (6.38) | 3.33 (3.47) | Wald $\chi^2(2) = 6.68$ $p = 0.04$ |

### 3.3 | Does parental goal completion relate to children's engagement or performance on the challenges?

Our analysis of goal completion focused on whether building circuits with a parent affected children's ability to build the same circuits on their own. We first considered the number of challenge circuits that dyads built during free play. Inspection of Table 2 reveals that this did not differ across the three parent–child interaction styles. There also was not a significant relation between the number of challenge circuits built during free play and children's age, $r_s(109) = 0.17$, $p = 0.08$. The number of challenge circuits dyads built during the free play phase did, however, significantly correlate with the proportion of challenges children solved in the challenge phase, $r_s(109) = 0.27$, $p = 0.004$, although it did not significantly correlate with the number of challenges children chose to participate in during the challenge phase, $r_s(109) = 0.14$, $p = 0.13$.

We wanted to ensure that it was not just that older children built more challenge circuits during free play and also solved a greater proportion of the challenges. We built hierarchical ordinal regression models with the proportion of challenges solved during the challenge phase as the dependent variable. We first considered age and the number of challenges children participated in during the challenge phase in Model 1, and then number of challenge circuits built during the free play phase as Model 2. Model 2 explained more variance than Model 1 (as measured by −2 Log Likelihood values), $\chi^2(1) = 5.60$, $p = 0.02$. Model 2 was significant, $\chi^2(3, N = 111) = 53.10$, $p < 0.001$, with main effects of all three independent variables, all Wald $\chi^2(1)$-values > 5.19, all $p$-values < 0.03. In contrast, when we built similar models with the number of challenges participated in (our measure of engagement) as the dependent variable, with age and the proportion of challenges solved during the challenge phase (Model 1), and then number of challenge circuits dyads built during free play as independent factors (Model 2), Model 2 did not explain significantly more variance than Model 1, $\chi^2(1) = 0.07$, $p = 0.80$. Unsurprisingly, Model 1 was significant, $\chi^2(2) = 54.45$, $p < 0.001$. To summarize, having the experience of building the challenges during the free play related to children's ability to build that challenge on their own, but not their engagement with the challenges.

We next examined whether constructing the particular challenge circuit during free play predicted children's successfully building that particular circuit in the challenge task. Because dyads constructed different numbers of electric circuits during free play, we constructed a General Estimating Equation (GEE) to factor out the within-subject variance if dyads built more than one circuit while playing together. We considered whether children successfully completed each challenge on their own (without hints or instruction) as the dependent variable. We treated challenge number (i.e., the difficulty of the challenge), children's age, and whether families constructed that particular circuit during free play as predictors. Age was a significant predictor, Wald $\chi^2(1) = 43.80$, $p < 0.001$, as was challenge number, Wald $\chi^2(7) = 130.17$, $p < 0.001$, indicating that children were more likely to complete the easier circuits on their own. More importantly, whether dyads built a challenge circuit during free play also predicted children's ability to solve that challenge on their own, controlling for the other variables, B = 0.49, SE = 0.20, 95% CI [0.09, 0.89], Wald $\chi^2(1) = 5.74$, $p = 0.02$.[3]

Given that constructing a circuit during free play related to children's ability to construct the same circuit on their own, we wanted to consider how parents' and children's actions and language while building the circuits related to children's performance on the challenges. We focused on moments when dyads completed one of the challenge circuits during the free play portion of the study, and examined two factors: (1) the number of actions (connections, disconnections, and button presses) made by both children and parents in the 30 s before and the 30 s after connecting each circuit, and (2) the number of causal utterances generated by both children and parents during this timeframe.

We constructed a GEE to factor out the within-subject variance, given that dyads often built more than one circuit during the free play. The dependent measure was whether children solved the challenge on their own. We looked at the role of age, challenge number (to control for the difficulty of the challenge), the number of actions performed by the child and by the parent in the 30 s prior to completing the circuit during free play, and the amount of causal utterances generated by the parent and the child during that time. Age was a significant predictor, with children more likely to solve challenges on their own as they got older, B = 0.05, SE = 0.01, 95% CI [0.03, 0.08], Wald $\chi^2(1) = 21.00$, $p < 0.001$. Challenge number was also a significant predictor, with the lower challenges more likely to be solved than the higher ones, B = −0.51, SE = 0.06, 95% CI [−0.63, −0.38], Wald $\chi^2(1) = 60.97$, $p < 0.001$. Examining parents' and children's actions and language, only parents' actions during the 30 s before completing the challenge during the free play was significant; the more actions parents generated, the less likely children were to complete the challenge on their own, B = −0.11, SE = 0.05, 95% CI [−0.22, −0.01], Wald $\chi^2(1) = 4.32$, $p = 0.04$. We ran a similar analysis for the actions and language generated in the 30 s after solving the challenge, and while age and challenge number were again significant, none of the other independent measures were, all Wald $\chi^2(1)$-values < 1.49, all $p$-values > 0.22.

To consider whether parental action interacted with age, we reran the GEE with only children's age, challenge number, and parents' actions as independent factors, looking at a factorial model. In this model, age was still a significant factor, B = 0.10, SE = 0.03, 95% CI [−0.03, 0.16], Wald $\chi^2(1) = 8.19$, $p = 0.004$. The only other significant finding was an age × parental action interaction, B = −0.01, SE = 0.006, 95% CI [−0.02, −0.001], Wald $\chi^2(1) = 4.45$, $p = 0.04$. To unpack this interaction, we performed a median split on children's age and looked at the relation between parental action in the 30 s before completing the circuit during free play and whether children built that circuit without hints or instruction during the challenges. For older children, the more actions parents generated leading up to the construction of the challenge circuit during free play, the less likely children were to solve the challenge, $r_s(186) = -0.15$, $p = 0.05$. This correlation was not significant for the younger children, $r_s(172) = -0.07$, $p = 0.39$.

### 3.4 | Do other language factors during free play relate to engagement or performance on the challenges?

The above analysis suggests that parental action, but not parental causal language in the 30 s before completing a circuit was related to children's ability to construct those particular challenge circuits on their own. A more general question is whether the overall amount of causal language generated by the dyad relates to children's performance. Furthermore, does parental encouragement, in the form of praise, relate to children's engagement?

Table 3 shows bivariate correlations among the number of challenges children participated in, and the proportion they solved without hints or instruction (the measures of engagement and performance we have used throughout) and the overall proportion of praise (and process praise specifically) that children heard, as well as the proportion of utterances parents and children generated that were classified as causal. Unsurprisingly, there was a significant correlation between the proportion of causal utterances generated by parents and children, $r_s(109) = 0.25$, $p = 0.008$, but there were no facets of language measured here that significantly correlated with either our measure of engagement or performance.

### 3.5 | Relations to demographics of the sample

Our final question concerns whether there were relations between demographics of our sample and our measures of children's engagement or learning. Parents' education level, household income, and attitudes towards science all did not differ among the three parent-child interaction styles, and none of these factors significantly related to measures of children's engagement or learning during the challenge phase, nor did they relate to the proportion of causal language parents or children generated during free play, all $r_s$-values < |0.12|, all *p*-values > 0.23. All other analyses (which were not significant) are reported in Supporting Information.

## 4 | DISCUSSION

This study investigated relations between parent–child interaction while playing at an open-ended electric circuit exhibit at a children's museum, and children's engagement and performance on a set of challenges with the same materials from the exhibit. In line with previous studies of guided play, we found that the ways parents and children interacted during play related to both engagement and learning at the exhibit (e.g., Callanan et al., 2020). Children whose parents were more directive in their interaction style while playing together chose to participate in fewer challenges. Children whose parents were more directive also tended to be slightly younger than the other two interaction styles, but critically, interaction style predicted a significant amount of variance beyond the effect of age and how well children could solve the challenges on their own. Interaction style also showed interesting interactions with age. Older children whose parents were more directive seemed to become less engaged with the challenges as they became more successful, a pattern that was different from the other interaction styles.

This finding provides novel insight into children's engagement with challenges on their own, as opposed to in more structured interactions. Medina and Sobel (2020) found that children from jointly-directed dyads were more engaged by a learning task than children in the other two dyad groups. Similarly, Callanan et al. (2020), who used a similar coding scheme to study parent–child interactions at gear exhibits in three children's museums, found that children from the jointly-directed group engaged in more exploratory behaviors that were predictive of their causal knowledge of the exhibit. This was different from the present study, in which children in the jointly-directed and child-directed groups were equally engaged by the challenge task, and both of these groups were more engaged than children in the parent-directed group. In both cases, the difference between the present study and these previous investigations concerns the engagement level of children in the child-directed group. Both Medina and Sobel (2020) and Callanan et al. (2020); however, looked specifically at measures of engagement while families played with museum exhibits, as opposed to engagement in a follow-up task where children participated on their own. Directive behaviors from parents might have more of an impact on engagement measures after the fact, particularly because children might rely on parents to set goals for them (or come to believe that they cannot set their own goals) and thus become less engaged overall when they are asked to do things on their own.

We used the parent–child interaction measure as a holistic measure of parents' and children's overall goal-setting as they played together. It is possible that parent–child interaction changes over the course of the play session. It does not seem surprising that within a play session, parents are directive at certain points, collaborative at certain points, and more hands-off at certain points. The metric we used captured coders' judgments of the session as a whole, based on what was happening for the majority of the dyad's free play. A question for future study is whether there are distinct patterns of interaction styles that unfold over the course of families' interactions with the exhibit. For example, would children's engagement be affected if parents were more directive at the beginning of playing with an exhibit or at the end, even if they were not directive overall?

Our holistic measure of goal-setting was related to children's engagement with the challenges, but not their performance on the challenges. What predicted children's performance was whether children and parents built that particular electric circuit during the free play phase, and if so, whether parents engaged in greater or fewer actions leading up to the completion of that circuit. The more actions parents engaged in during the 30 s prior to completing the circuit during the free play, the less likely children were to complete the circuit on their own. Together, these findings indicate that parents' involvement in setting goals for children and in building electric circuits at the exhibit were negatively associated with children's engagement and performance when they were asked to build the same circuits independently.

This effect of parents' actions also interacted with children age, disproportionately affecting the older children in the sample more than the younger children. A possible interpretation of this finding is that when parents engaged in more actions than their children while playing together, the older children in our study may have interpreted their parents' actions as indicating that they were less capable of building the circuit themselves (prompting them to simply ask for help or seek out direct instruction during the challenges).

Contrary to our expectations, parents' causal language did not predict children's engagement or success on the challenges. Similarly, the extent or type of praise parents generated did not relate to children's willingness to engage with the challenges. This differs from previous findings suggesting important roles for both causal language (e.g., Crowley et al., 2001; Rowe et al., 2017) and praise (e.g., Gunderson et al., 2013; Master et al., 2017) in children's engagement and success in parent–child interaction. However, it is possible that such causal language and praise must be in the same context as the parent–child interaction. Given that children were tested on the challenges without their parent, this might have limited the generalizability of these language effects.

There are also strong effects of parental causal language documented in the scaffolding literature, in which parents are often explicitly trying to teach their children or help them accomplish a goal (e.g., Philips & Tolmie, 2007). In the present study, parents might not have had the goal of teaching their child about electric circuits, since the exhibit (and the children's museum setting in general) prompted families to play, explore, and experiment, and since the circuit blocks may have been unfamiliar to parents as well as children. As a result, parents' verbal interactions may not have focused on scaffolding or instruction.

Finally, we did not find significant relations between parental demographics information, such as their household income or

**TABLE 3** Correlations among engagement, learning, and language generated by parents and children, all $r_s(109)$-values

| | % of process praise | % of all kinds of praise | % of causal language (parents) | % of causal language (children) |
|---|---|---|---|---|
| Engagement | −0.02<br>*p* = 0.83 | 0.05<br>*p* = 0.63 | 0.13<br>*p* = 0.17 | 0.05<br>*p* = 0.58 |
| Learning | −0.01<br>*p* = 0.90 | 0.02<br>*p* = 0.85 | 0.04<br>*p* = 0.65 | −0.06<br>*p* = 0.57 |

education level, and facets of the dyad's play or children's engagement or success on the challenges task. Although our sample did show a relatively heterogenous distribution of household income (see Table S1), the sample did have a relatively high level of education overall, with 75% of participating parents reporting their education level having a B.A. or higher. It is possible that a more diverse sample would reveal relations between parental education level and parent–child interaction behaviors. It is also possible that parental education level relates to scaffolding at home, but not necessarily parent–child interaction in museum settings. Several studies of parent–child interaction in museum settings have found no correlations between parent–child interaction and parental level of education (e.g., Callanan et al., 2020; Perez & McCrink, 2019). More research is necessary to reconcile these findings with the numerous studies documenting the role of parental education level in scaffolding (see Mermelshtine, 2017).

More generally, it is possible that parent–child interaction is different in children's museums compared to the home or the lab because of the presence of other families or the presence of materials that were designed for purposeful interaction. While we acknowledge that there are differences between interaction in designed and facilitated environments and other types of informal settings, museums can offer a window into parent–child interactions in the context of children's everyday lives (Callanan, 2012; Sobel & Jipson, 2016). As spaces intended to support exploration, they can also support rich interactions around STEM concepts and practices (Bustamante et al., in press; Hassinger-Das et al., 2020; Ridge et al., 2015).

A limitation of this study is that it examined parent–child interaction in one cultural context, and is therefore not meant to generalize to parent–child interaction globally. Parent-child interaction varies across cultural contexts. For example, parents in the U.S. frequently use a direct, active teaching style typical of formal education (Little et al., 2016). Other studies of caregivers from Non-Western populations have found different patterns. For example, Clegg et al. (in press) found that caregivers in Vanuatu were more likely than U.S. caregivers to divide tasks with children based on difficulty; Rogoff and colleagues (e.g., Rogoff, 2014) have found that caregivers in rural Guatemala and Mexico were more likely than U.S. caregivers to expect children to learn through observation rather than direct instruction. Future research should examine cultural variation in the relations we observed between interactional style and learning outcomes.

To conclude, these findings illustrate the importance of examining the nuances of collaborative interactions between parents and children in order to gain a deeper understanding of how parental involvement affects not only children's learning, but also their attitudes and motivations to learn in real-world contexts (Weisberg et al., 2014). This work has implications for pedagogical practices and design decisions in informal learning environments that seek to engage parents and children together. Our results not only highlight the importance of children's agency in choosing their own goals and making their own discoveries, but also show the value of responsive support from parents to encourage children's exploration, engagement, and learning.

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## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

## ENDNOTES

[1] Technically, this analysis required a sample size of 113 participants, but because we were testing at a museum on specific days, we were limited to what we were able to collect.

[2] Adding the interactions also did not improve the fit of the model.

[3] To ensure that the scaffolding we used to administer the challenges did not affect whether children solved subsequent challenges, for both this GEE analysis and the subsequent ones we report, we also ran a GEE in which we included as a dependent variable whether children had received hints or instructions on previous challenges. This factor had no significant effect on this GEE or the subsequent one that we report, and none of the other variables' significance levels change when this factor was included. As a result, we chose to report the models that did not include this factor.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

Supplementary Material

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