EXPECTANCY-VALUE AND CHILDREN'S SCIENCE ACHIEVEMENT:

PARENTS MATTER

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Abstract

This longitudinal study explored the ways parents' and teachers' expectancy for success influences 3rd – 5th children's expectancy for success and achievement in science. Guided by an open-systems perspective and functional (Ballantine & Roberts, 2007) and expectancy-value (Eccles, 2005; Eccles, 2007) theories, we focused on school related socialization processes and the role of parents and teachers in shaping children's abilities and skills. Participants included 153 children from 23 rural, Oklahoma schools and provided matched sets of parent, teacher, and child surveys. Weisgram and Bigler's (2006) science self-efficacy subscale organized survey items where wording changes allowed parallel parent and teacher versions of the scale. Achievement was determined by test scores on the state-administered Oklahoma Core Curriculum Tests (OCCT). Results showed teachers' expectancy for children's success in science did not significantly predict students' fifth grade science achievement. However, regression analyses showed parents' expectancy did predict students' fifth grade science achievement. The relationship was statistically significant and explained about 19% of the variance in fifth grade science achievement test scores ($R^2 = .19$). We further determined that children's science self-efficacy significantly influenced science achievement scores ($\beta = .20$) (however this was a far weaker influence than the direct effect of parents' expectancy ($\beta = .38$) of children's success in science). The novel finding is that parents have an influence on children's achievement over and above children's own self-efficacy beliefs about science. Clearly, parents matter when it comes to science achievement. Though it seems parents are more influential than teachers when it comes to children's own expectations and achievement success in elementary science, we encourage further consideration of parent expectancy as it relates to child ability and achievement, modified classroom strategies, and home-school relations to better align teachers' positive influence on children's expectancy for success.

Keywords: *Parents; Motivation; Science; Achievement; Expectancy-Value*

Expectancy-Value and Children's Science Achievement: Parents Matter

While the achievement of students' across school subjects is important, recent national initiatives and other factors continue to drive researchers' and educators' ongoing interest in maximizing science achievement (The National Commission on Excellence in Education, 1983; National Research Council, 1996, 2012; National Science Foundation, 2004; National Academies Press, 2007). Some researchers have focused on the stratification of students' college-related trajectories (Mullen, 2010) and efforts to advance achievement in gateway or introductory science courses and persistence in science majors (Ceglie & Setlage, 2016; Chen & Soldner, 2013; Pascarella, et al., 2004; Phinney & Haas, 2003). Others have focused on high school students' development of career interests, formation of ideas about the work of scientists, and selection of advanced science courses (Asbacher, Ing, & Roth, 2010; National Research Council, 2006). Yet others point to middle school students' experiences as pivotal to later decision points in high school and college (American Association for the Advancement of Science, 2011; Gonzales et al., 2004; Sadler & Tai, 2001). We argue that early experiences with science are foundational to later attitudes about and interest in science (National Research Council, 2007). In other words, studies of elementary school science may provide vital understanding about how achievement gaps form and guide recommended interventions for researchers, educators, and policy makers. While our larger longitudinal research study set out to link home, school, and community influences on 3rd – 5th graders' interests, attitudes and achievement in science and mathematics in the socio-cultural environs of rural elementary schools in Oklahoma (largely low-SES and American Indian (AI) students), the present study focused on understanding the combined roles of parents and teachers in the early formation of children's interests and expectations in elementary science learning.

Theoretical Perspectives

The present study is organized by an open-system perspective and channeled by two theories: modified intersectional theory and expectancy value theory. *Open systems perspective* informed our broad view of the ways in which parents and teachers negotiate the socialization process of schools. *Modified intersectional theory* guided our exploration of rural students' pursuit of science tracks and *functional theory* guided our analysis of the broader processes of socialization in schools and the culture of expectations shared by parents, teachers and students in forming children's abilities and skills. *Expectancy-value theory* guided our exploration of the independent roles of teachers and parents in influencing boys' and girls' motivation and achievement in science. In sum, this focused analysis of parents' and teachers' longitudinal influence on children's science achievement began with a broad view of schools as an open-system and attended to the functional system of parents' and teachers' shared roles in the socialization process of schooling. Expectancy-value theory then guided particular focus on parents' and teachers' independent roles in influencing boys' and girls' motivation and achievement in science.

Open Systems and the Process of Socialization in Schools

Open systems perspective (Ballantine & Spade 2008) managed our view of school organization as a social system (see Figure 1). The *school organization* might represent the whole school system; a particular classroom within a school; or interactions between teachers, students, parents and other children. Though the organization is where the activities take place, the organization's boundaries are not fixed: people who lead organizational activities are influenced by *input* (student demographics, teachers, and teacher preparation) and *output* (new knowledge, emerging culture, and readiness for STEM). Open-system interactions or *feedback*

are mediated by the *environment* outside the organization (state and national standards, school board members, community, and cultural values). Additionally, this open systems model recognizes that parents, teachers and students do not operate in a vacuum. Rather, they are constantly responding to demands from both inside and outside the organization; the boundaries of the organization are fluid. We were particularly interested in these relational dynamics given the unique study *environment* (low SES, rural Oklahoma schools within the confines of seven American Indian (AI) tribal nations). The usefulness of the open systems model is that it allowed us to isolate components to capture both the micro (discrete) and the macro (aggregate) levels of analysis. Figure 1 illustrates the functions of this sociological model and highlights the foci of this study with a macro-lens set on the organizational dynamics of STEM readiness or science achievement (as output) and the micro-lens set on the relationship between parents' (family input) and teachers' (school organization) contribution to children's achievement or STEM readiness (output).

Following a *modified intersectional theory* framework, this research plan employed an interdisciplinary viewpoint to better understand the racial or gendered dynamics (Hesse-Biber & Yaiser 2003, Weisgram & Bigler 2007) in the pursuit of STEM (science achievement) among rural 3rd – 5th grade boys and girls (largely poor and AI). *Intersectional theory* holds that discrete forms or expressions of oppression (such as race, class and gender) actually shape, and are shaped by, one another (Collins, 2000). By employing intersectional theory as a framework, this research plan avoids historically simplistic and distorting approaches that have assumed discrete entities (such as schools, teachers and parents) operate independently rather than interdependently (Anderson & Collins, 2007). *Functional theory* guided our focus on broader processes of socialization in schools related to the creation of a culture of expectations shared by

parents, teachers and students in shaping assumptions about children's abilities and skills (Ballantine & Roberts, 2007). This perspective guided our expectation that parents and teachers would help to form children's beliefs and values pertaining to science (e.g. Eccles et al., 1983; Pekrun, 2000).

Expectancy-Value Theory and Science Achievement

One way of organizing and understanding influences on children's science achievement is through expectancy-value theory (Eccles, 2005; Eccles, 2007). Though it was originally developed as a way of understanding how and why children were motivated toward mathematics (with particular emphasis on understanding gender gaps in mathematics), expectancy-value theory has been expanded and used across a variety of learning domains (Eccles, 2007). Two basic components of expectancy-value theory inform the ways children are motivated toward a subject, and thus how they achieve and persist in that area: *expectancy for success* (often used interchangeably with self-efficacy) and *subjective task value*. It has been a relatively consistent finding that expectancy for success (or self-efficacy) will predict children's achievement, while subjective task value (such as usefulness or utility value, and enjoyableness or intrinsic value) will predict persistence and selection of the subject area given a choice (Wigfield & Eccles, 2000). In one application of this, Watt, Eccles, and Durick (2006) found the main difference between college-aged men and women was only in subjective task value, which explained the relatively low differences in achievement (predicted by self-efficacy or expectancy for success) versus larger differences in persistence and choice (predicted by subjective task value); the women expected they could do the work at the same rate as men, but they did not find the work as enjoyable or valuable as did the men.

In the field of elementary science teaching and learning, researchers have explored students' interest and persistence in science classes, and their interest and understanding of science careers. Simpkins, Davis-Kean, and Eccles (2006) found that participation in science activity was predictive of self-efficacy and subjective task value, suggesting that exposure might increase motivation. They further found that, while participation increased expectancy and subjective task value, self-efficacy predicted the grades students earned. Further, Aschbacher, Ing, and Tsai (2014) found that students with lower self-efficacy in science also held lower aspirations for learning and doing science. According to the expectancy-value model, parents and teachers hold beliefs and engage in behaviors that shape boys' and girls' beliefs and academic motivation. LeGrand (2013) found that gender differences in expectancy and value existed in science across grade levels, beginning in elementary school and growing into high school, potentially offering an explanation for gender gaps in science majors and careers. Thus, in elementary science, it seems that expectancy for success plays a strong role in predicting students' persistence and success, much as it does in other areas of STEM education.

Parent and Teacher Influences on Science Learning and Achievement

Researchers have explored the ways in which parents and teachers seem to influence boys' and girls' science attitudes, interests, and achievement in one way or another. Some researchers have linked teachers' beliefs directly to students' achievement (Ee, Moore, & Atputhasamy, 2003) while others have more strongly linked parents to such belief-outcome dynamics (Friedel, Cortina, Turner, & Midgley, 2007). The following review organizes current knowledge related to teacher and parent influences on boys' and girls' science values, attitudes, and achievement.

Teacher Influences on Science Learning and Achievement

One source of influence on science learning and achievement, that is perhaps intuitive and is often researched, is the role of teachers. Their role in classroom instruction situates teachers as a direct arbiter of children's experience with science. Multiple studies point to teacher effectiveness as the dominant factor affecting student gains (Ceglie & Settlage, 2016; Darling-Hammond & Hudson, 1988; George & Kaplan, 1998; Kostantantopoulos & Hedges, 2004; Wright et al., 1997). Simply put, teacher quality indicators can inform our assessment of science learning and achievement.

Values/Attitudes/Beliefs. Teacher beliefs are more influential than academic knowledge when it comes to making teaching decisions (Brophy, 2008; Bryan, 2012). Thus, teachers communicate their beliefs about science through classroom practices (Luft & Roehrig, 2007; Wallace, 2014). Other researchers agree that teachers' own achievement orientations influence their instructional approaches (Butler, 2012; Rolland, 2012). In a large-scale professional development research effort, Haney, Lumpe, Czerniak, and Egan's (2002) found a positive relationship between elementary teachers' increased science teaching self-efficacy and student science achievement. Thus, teacher-led science activities are known to affect students' science attitudes and achievement—directly and indirectly (Haladyna & Shaughnessy, 1982; George & Kaplan, 1998). .

Good's (1981, 1987) seminal research on teacher expectations explored the unintended ways teachers' performance expectations mediated student learning. He raised concern for teachers' differential treatment of high and low achievers (i.e. paying less attention to low achievers) and reasoned teacher treatments affect students' self-concept, achievement, motivation, and levels of aspiration. In a more recent study of teacher-effect, Schroeder, Scott, Tolson, Huang, and Lee. (2007) analyzed 61 studies of science achievement as classified by

teacher treatments (questioning strategies, focusing strategies, enhanced materials, assessment strategies, inquiry strategies, instructional technology strategies, and collaborative learning strategies). They found the most effective teachers employed enhanced context strategies (i.e. connecting topics to students' previous experiences) to engage student interests and help students relate new topics to previous experiences or prior learning.

Teacher Quality. Research consistently shows that teacher quality is strongly related to student achievement (Darling-Hammond, 2002). That is, regardless of classroom context, skilled teachers (as measured by content knowledge, academic ability, experience, and training) produce higher achieving students. (Center for Public Education, 2015; Nye, Konstantopoulos & Hedges, 2004; Wright, et al., 1997). These findings suggest that elementary science teachers wield heavy influence on children's science achievement regardless of their ethnicity, class, or school site. Brown and Medway's (2007) case study of exemplary teachers in South Carolina highlighted the benefits of high standards and expectations (i.e. all children can learn) and learning methods that encourage autonomy and independent thinking [over the more traditional, didactic methods generally applied to low-income and disadvantaged students (Means, Chelmer, and Knapp, 1991)]. With an eye to measured teacher-effect on student achievement, the National Science Board (2014) pointed to the importance of teachers' continuous professional development and raised concern for elementary teachers' limited participation in science-focused professional development.

As our open-systems perspective (Figure 1) suggests, teachers' beliefs (Kelley-Jackson & Jackson, 2011) and attention to culturally relevant pedagogy (Ladsen-Billings, 2009) “. . . helps students understand and participate in knowledge-building” (p. 88). Thus, Brown and Medway (2007) explained successful teachers in poor communities build mutually supportive learning

environments that enable flexible instructional strategies and shape a working relationship between the school and families. With respect to AI students, Aikenhead (1997) expected quality science teachers necessarily negotiate students' personal orientations as well as their family and tribal nations' values and beliefs related to school science. Thus cross-cultural methods (with the teacher as "tour guide, travel agent, or culture broker" (p. 232) help students facilitate "border crossings" (p. 224).

Parent Influences on Science Learning and Achievement

Parents, too, are involved in the science learning and appraisal process. As Ceglie and Setlage (2016) explained, parents wield cultural capital in handing down familial norms, skills, and habits. Parents may be involved in homework, express their views about science directly or behaviorally, and share more time with their children (and thus carry more influence with their children) than teachers. As with teachers, parents' beliefs and goals broadly impact children and their achievement (Ceglie & Setlage, 2016; Villegas & Lucas, 2002). For example, children with performance-oriented parents are more likely to have performance goals themselves (Gonida, Kiosseoglou, & Voulala, 2007). It seems parents' achievement goals are associated with students' academic outcomes (Audet, Evans, Williamson, & Reynolds, 2013). These same findings have been replicated in elementary science classrooms (Kahraman & Sungur-Vural, 2012) and suggest parents' goals (over school goals and peer influence) better predict children's motivation (Vedder-Weiss & Fortus, 2013).

Value/Attitudes/Beliefs. More broadly, Perera (2014) found that parents' attitudes toward science and science learning have a strong impact that functions independently (from other child and school variables) on achievement. Her analysis of the Program for International Student Assessment (PISA) data across 15 countries showed parent attitudes positively affected

science test scores. Children may perceive parents' interest and support of science via family outings to science museums and exhibits (Lee & Schute, 2010). Parents school-oriented behavior, like positivity and working with children on science, also appears to contribute to science achievement (Simpkins, Price, & Garcia, 2015). However, much of this influence appears to come from interactions at home. Though Johnson and Hull (2014) found that parents' involvement at school did not predict achievement in science, parents' influence on children's achievement (via parents' beliefs about science) is both immediate and long lasting (Ing, 2004; Froiland, Peterson, & Davison, 2013).

In reviewing the science education literature, Rodriguez, Collins-Parks, and Garza (2013) concluded that parents have a significant and stable impact on children's academic self-concept, self-efficacy, and achievement via their own expectations for their children. These influences tend to be domain-specific, such that a generally positive parental expectation is not sufficient to result in positive a child's self-efficacy in science. Rather, the parental expectation for science success must be high (Yeung et al., 2010).

Achievement. Froiland, et al. (2013) found that parental expectations for science in kindergarten influence not only immediate achievement, but are also positively related to achievement in the eighth grade as well. In particular, parental involvement seems to be related to child expectancy for success in science and science achievement. Perera (2014) found that parental involvement was directly tied to student science achievement, and that students from disadvantaged backgrounds appeared to benefit even more from such involvement. This relationship may flow through expectancy for success as Shumwow and Schmidt (2014) found that parental involvement in their children's science work was directly related to the child's perception of his/her ability in science. These researchers reasoned parents continue as critical

school partners through the early years of high school and found parental involvement in their ninth graders' science work was directly related to the child's perception of his/her ability in science.

Method

In the larger project from which the present study is derived, our longitudinal research interests focused on the interdependence of school and home cultures on rural, largely low-income and American Indian, 3rd – 5th grade students' interests and expectations in elementary science learning. We intended to determine the significant predictors of low-income, rural American Indian boys' and girls' early interests in STEM and to inform policies and procedures that improve classroom practices and maximize opportunities to expand STEM career fields for all. In the present study, we focused on the intersection of parent and teacher influence to explore the relationship between the sociological construct of public schools (defined by open systems), employing modified intersectional theory in the exploration of racial or gendered dynamics in these rural students' pursuit of science tracks and expectancy-value theory where teachers' and parents' collective expectancy for children's success in science might influence both the child's motivation and achievement in science. Our analysis was organized by four hypotheses:

1. Teachers' expectancy for student success and parents' expectancy for their children's success in science would predict children's expectancy for success in science and achievement in science.
2. Children's expectancy for success in science would predict their achievement in science.

3. Parents' expectancy for success in science would have an indirect influence on children's achievement (through their expectancy for success), resulting in a partial mediation of the direct influence.

4. The relationships among parent expectancy, teacher expectancy, student expectancy, and achievement would operate similarly for girls and boys.

Participants

Participants included elementary school children and their parents and teachers in 23 rural, Oklahoma schools within a 50-150 mile radius of the research base. We initially collected survey data from children (and their parents and teachers) enrolled in the third grade, and then attempted to follow those same children as they progressed through the fourth and fifth grades. In this, we offered participation to all 4th and 5th graders in these same 23 schools.

One natural consequence of this longitudinal study was that some participants were lost due to transfers, moves, and other reasons that took students out of these schools, while other students moved into these same schools. In the first year, we surveyed 585 third grade children. In the second year, we surveyed 796 fourth grade children. Finally, in the third year, we surveyed 784 fifth grade children. However, while we have survey data on 324 children for at least two years, we only have continuous survey data on 220 of these children for all three years. Part of the attrition from year-to-year is aligned with school trends. The total number of students in the schools sampled varied widely from year to year, with a maximum of 1,103, and minimum of 794 students enrolled across the combined 23 schools. There is additional evidence that at least some of the attrition was related to year-to-year movement in and out of the district. Approximately 166 checks, mailed to parents as incentive payments for completing surveys, were returned by the post office or never cashed, suggesting many of those families may have

moved (perhaps resulting in attending a different school). Taken together, the schools surveyed showed 28.11% drop in enrollment during the three years of the present study, and about 14.2% of the parent survey checks were undeliverable or never cashed. Based on these indicators, we concluded that the number of full data sets we had was related to trends in the schools in enrollment.

The number under analysis in the present study was further limited to those children whose maternal parent (i.e. mother, stepmother, and grandmother) also completed and returned surveys to yield a final sample of 153 matched sets of parent, child, and teacher surveys for all three years. With this, we excluded 10 data sets where the parents were paternally related to the child (i.e. father, stepfather, grandfather, etc.) due to the apparent outlier status of paternal parents in the analyses described.

Among those 153, there were 66 boys and 87 girls. In terms of children's ethnicity, there were 102 reported as white, 30 as Native American, 6 as multiethnic, 3 as Hispanic, 2 as African American, 1 as Asian, and 9 as 'other', with one not reporting ethnicity. Parent's reported their education level as follows: 4 were less than high school, 29 high school, 6 some vocational education, 10 vocational education graduate, 48 some college education, 43 college graduate, and 13 graduate or professional degree. In terms of household income, 7 reported income of less than \$12,000 per year, 36 between \$12,000-\$24,000 per year, 37 between \$24,000-\$36,000 per year, 31 between \$36,000-\$48,000 per year, and 52 over \$48,000 per year, with one not reporting household income. Approximately 28% of the families in this sample were below the federal poverty threshold, as compared to 15.3% of families in the state, and 14.8% of families nationwide during the same period (U.S. Census Bureau, 2013).

In order to assess the representativeness of the sample for students enrolled in the schools involved in the study, we used the chi-square test for goodness-of-fit. There was a significant difference in the racial composition of the sample versus the school population ($\chi^2_5 = 28.87, p < .001$). Specifically, Native American/American Indian students were underrepresented in the sample ($SR = -2.21$), as were Hispanic/Latino students ($SR = -2.82$), while White students were overrepresented in the sample ($SR = 3.56$). Worth noting is that, for this chi-square analysis, we had to exclude students who identified as “other” and “multiracial” because available enrollment data do not include those categories. As a result, it may be that the sample is more representative than the analysis indicates due to a mismatch between how race data were collected versus how the district reports enrollment.

Procedure

The research team visited each of the 23 participant schools 4-5 times each year (with variations due to absences and make-up surveys). Research participants (children, their parents, and their teachers) completed annual surveys over a three year period of time. Initially, superintendents and principals gave consent via signed letters for their schools to participate in this study. Each year thereafter, building principals helped facilitate meetings with grade level teachers to begin delivery of the teacher surveys, distribution of the parent permission forms, and arrangements for the day and time students would complete the survey packets. Teachers would complete their surveys prior to children’s survey date, thus allowing the research team to collect child and teacher surveys in person and on the same day. Each child, teacher, and school was assigned a unique identification number. Identification numbers were verified by multiple research team members to assure accuracy and helped to match parent, teacher, and child survey responses.

Parent permission forms were worded such that parents could check a box indicating their consent (either: yes, my child may participate; or no, my child may not participate). Teachers sent parent permission forms home with students and were incentivized to assist in facilitating the return of parental consent forms. In this, teachers were paid \$1 for each returned form. Children were presented an information-about-the-study sheet and signified their assent as they completed the demographic data form on the front of the survey packet. Child surveys were completed during regular school time (about 30 minutes) and scheduled at a time identified by the classroom teachers. Those students who did not return a parent form, or whose parents did not approve of their participation, usually remained in the classroom and read a book during the survey administration time.

On the day of the child survey, at least one research team member visited the school to provide instructions, hand-out/collect survey packets, and to verify the participant numbers. In larger schools multiple research team members (at least one per classroom) assisted with data collection. The research team member read-through the various sections of the survey as children responded--explaining any new vocabulary terms and insuring children understood the Likert scales (as they varied across the constructs). Once students had completed their surveys, the research team member gave students the previously prepared parent-packs, which students took home to their parents. These parent-packs included the parent survey forms, a stipend offer (to incentivize parent participation), and a self-addressed, stamped envelope. Parents, who mailed survey forms back to us, received a \$30 check by return mail for completed survey forms.

This process was completed each year: for third grade classes in the first year, fourth grade classes in the second and fifth grade classes in the third. After all three years of data had been gathered, sets of child-parent-teacher data were matched according to participant

identification numbers, and all identifying information was destroyed. These procedures were approved by the University Institutional Review Board.

Materials

The children's complete survey battery included all items from the Weisgram and Bigler (2006) survey (egalitarianism, self-efficacy, utility, and interest). For this study, we focused on the *self-efficacy subscale* which we modified to reflect *parent's expectancy for their child's success*, and *teacher's expectancy for their students' success* (see Table 1 for all items across all three versions of the scale). The child version of this subscale contains seven items (sample item: "I know I can do well in science"). In the present sample, the scores showed good reliability ($\alpha = .80$). For the parent version, we modified the scale by changing the wording to reflect their expectancy for their child's success in science. For example, the item, "I know I can do well in science," became, "I know my child can do well in science." The parent version of the scale contained a total of ten items, and also produced good score reliability in the present sample ($\alpha = .86$). We made similar wording changes to create a teacher version of the scale, which contained ten items (sample item: "I know my students can do well in science"). The teacher version also produced good score reliability in the present sample ($\alpha = .88$). The teacher and parent versions contained more items than the child version due to an effort to shorten the child version (and limit the overall survey time during the school day). Additionally, the subscale was not administered alone, but as component to the full Weisgram and Bigler (2006) science attitude scale. However, only the self-efficacy for science, expectancy for child's success in science, and expectancy for student's success in science subscales are analyzed in the present study.

Achievement was determined by test scores on the state-administered Oklahoma Core Curriculum Tests (OCCT). State data suggest that score reliability was between $\alpha = .85$ and $\alpha =$

.91 for the years in which we collected data. The OCCT science scale, which we use here to measure science achievement, consists of 86 items spanning various content areas (Oklahoma State Department of Education, 2013). Specifically, the test measured ‘Observe and Measure’ (11 items), ‘Classify’ (9 items), ‘Experiment’ (13 items), ‘Interpret and Communicate’ (12 items), ‘Properties of Matter and Energy’ (17 items), ‘Organisms and Environments’ (12 items), and ‘Structures of the Earth and the Solar System’ (12 items). In the present study, we worked with raw test scores obtained from the schools, allowing more detailed analysis than the State’s standard scores or categorical transformations of these scores.

Results

One of the initiating purposes of this National Science Foundation-funded study was to determine how gender influences perceptions of science and pursuit of science coursework and careers. As such, we ran initial analyses to determine if gender was related to differences in science self-efficacy or value. Using a multivariate analysis of variance (MANOVA), we tested whether the set of dependent variables in this study (including science achievement, science expectancy for success, and perceptions of utility value for science) would significantly differ based on gender. There was no significant difference based on gender ($\Lambda_{3,174} = .994, p = .793, R^2 = .006$). To further explore demographic factors, we ran the same test based on child race. Similarly, the set of variables did not significant differ based on child race ($\Lambda_{3,170} = .932, p = .673, R^2 = .068$). Finally, we similarly tested for differences based on family income. There were no significant differences in the set of variables based on income ($\Lambda_{3,30} = .887, p = .915, R^2 = .123$). Because no significant differences existed in the set of salient variables based on these demographic factors, we moved forward with analyses not split by demographic factors.

We began by testing whether teachers' expectancy for their students' success in science (measured at the third grade) had any direct influence on science achievement (measured at the fifth grade) using simple linear regression. There was no significant influence ($F_{1,237} = .04$, $p = .843$, $B = .31$, $SE_B = 1.55$, $\beta = .01$) based on third grade teacher data predicting fifth grade science achievement test scores. We tested the same relationship among concurrent data, where both teacher expectancy for their students' success in science and science achievement were measured at the fifth grade. Again, there was no significant influence ($F_{1,252} = 1.93$, $p = .166$, $B = 4.43$, $SE_B = 3.19$, $\beta = .09$). Because there was no direct influence, a mediation analysis was unnecessary. As a result, in subsequent analyses, we focused on parental influence.

To understand parental influences, we began by testing the relationship between parents' expectancy for their children's success in science (as measured during the third grade) and science achievement scores (as tested during the fifth grade) using simple linear regression. The relationship was statistically significant ($F_{1,164} = 37.28$, $p < .001$, $B = 12.79$, $SE_B = 2.10$, $\beta = .43$), and explained about 19% of the variance in fifth grade science achievement test scores ($R^2 = .19$). We hypothesized that the influence of parents' expectancy for their children's success on science achievement scores might be mediated by children's self-efficacy scores. As a result, we used path analysis to test a mediation model, as shown in Figure 2. Although the influence of parents' expectancy for their children's success in science on achievement scores was slightly mediated, the total direct effects remained at .38, a slight drop from .43 in the simple linear regression, with only .04 moving to indirect effects mediated by children's self-efficacy for science. Further, although children's self-efficacy for science had a significant influence on science achievement scores ($\beta = .20$), this was a far weaker influence than the direct effect of parents' expectancy ($\beta = .38$) for their children's success in science.

We tested the same model for invariance across child genders. That is, we tested to determine if there might be differences in the influence of parent expectancy on child expectancy and achievement on boys and girls independently. The unconstrained model was a much worse fit than the model with constraints imposed making the two groups equivalent ($\Delta\chi^2_9 = 21.10$, $p = .012$, $\Delta CFI = .265$, $\Delta TLI = .037$). As a result, we concluded the model was invariant across student gender, meaning that the originally specified path coefficients are equivalent in both boys and girls. It should be noted that this does not imply there were no mean differences between boys and girls, only that the relationships among the variables are similarly structured in both genders.

Based on these results, it seems that the influence of parent expectancy on child self-efficacy for science and science achievement is equally strong for both boys and girls. The results also suggest that in the present sample there is no direct or mediated influence of teachers' expectancy for students' science success on achievement tests, but there is a direct influence for parents' expectancy, which is only slightly mediated by children's own self-efficacy.

Discussion

In the present study, we focused on the intersect of parent and teacher influence to explore the relationship between the sociological construct of public schools (defined by open systems), modified intersectional theory in the exploration of racial or gendered dynamics in these rural students' pursuit of science tracks, and expectancy-value theory where teachers' and parents' collective expectancy for children's success in science might influence both the child's motivation and achievement in science. Therefore, we explored the ways parents' and teachers'

expectancy might influence the child's expectancy for success in science and the child's achievement in science.

Teacher influence. Our hypotheses about teachers' influence were not supported: teachers had neither a direct nor an indirect influence on children's expectancy for success. This was unexpected—especially given the large body of research on the impactful ways teacher quality influences student achievement where teachers matter more to student achievement than any other aspect of schooling (Darling-Hammond, 2002). Looking to our open systems perspective, two processes with the school organization may define driving forces. First, elementary science seemed to suffer unintended consequences from federal and state 'accountability' policies, beginning with the No Child Left Behind (NCLB, 2001) legislation, and continuing in current paradigms across the U.S. As it happens, such 'accountability' programs seemed to narrow the science curricula by guiding teachers' decisions to decrease time spent on science instruction in order to focus more time on improving students' reading and mathematics achievement (Griffith & Scharmann, 2008). Thus, since mandated science testing in Oklahoma does not begin until 5th grade, 3rd and 4th grade teachers in our study might not have been as highly invested in science achievement as in reading and mathematics achievement.

Our findings in the present study did not support a significant influence of teachers' expectancy beliefs on children's achievement. As such, we are hesitant to opine much on the nature of teacher influences. However, within the broad 'accountability' systems described above, we theorize that science influences may have been limited by a curriculum not focused on science, and informed by cultural factors that invest more authority in family and community sources than educators, particularly among rural, low-income students, many of whom were American Indian.

As the RAND Corporation (2012) explained, though non-school factors (such as family characteristics) do influence child achievement, they garner limited notice since they remain largely outside a school's control. While family characteristics may have four to eight times the impact teachers have on student achievement (RAND, 2012), policy discussions continue to focus on teachers because it seems easier to improve teaching than to change children's family circumstances. These study results confirm family influence on child achievement and raise policy concerns about how to best wield the power-brokering between school and home when it comes to science learning.

Parent influence. Our hypothesis about parental influence was partially supported: the prediction of science achievement by parental expectancy for child success in science is only partially mediated by child self-efficacy in science. It seems, however, even after taking into account the way parent expectancy flows through child expectancy to influence achievement, much of the direct influence of parent expectancy on child achievement is still unexplained. Thus, it may be important to re-consider policies and procedures that link parents with school efforts to increase and improve children's science achievement. We expect, too, new parent-teacher partnerships would help diminish the widening, performance-gap between high-income and low-income students (National Research Council, 2007).

It is clear from these findings that parents influence children's beliefs and achievement in ways that have previously been largely unexplored. The link between parents' beliefs and children's achievement is not fully explained by the present study. This finding calls for deeper, perhaps qualitative or observational, research on how, why, and when parents' beliefs make a difference in children's achievement. Such research may lead to intervention strategies that are effective in improving children's achievement via parental involvement.

Gendered expectations. Our hypothesis about the gender differences in structural relationships among parent, teacher, and child expectancy was not supported: maternal parents' (i.e. mothers, step-mothers, grandmothers) seemingly had equally strong influence on boys and girls, given that there were no gender differences across the set of dependent variables. That is to say, though these maternal parents may have had different expectations of boys and girls, their influence was similarly strong for boys and girls. These results are novel because research suggests maternal parents' have different expectations of their sons and daughters (Gunderson, Ramirez, Levine, & Beilock, 2012; McGrath & Repetti, 2000). We did not, however, capture the race and culture dimensions of understanding we hoped for in this participant pool. We expected to learn more about similarities and differences of AI and non-AI boys' and girls' science efficacy and expectancy among children, teachers and parents. We also hoped to achieve early-indicators of AI and non-AI, girls and boys, STEM-readiness trajectories just as Mullen (2010) sought to learn how high school students' social background contributed to college attendance and majors.

Limitations

There are several limitations to the current study. To begin, our data were limited to self-reported, survey responses of parents, teachers and children. Although surveys have been a common way of measuring expectancy-value, additional data sources would improve our understanding. For example, it would enlighten the results to gather more data about how and when science was taught in these schools. As Osborne, Simon, and Collins (2003) argued, the historic, fact-based curricula model does not encourage or direct teachers to capitalize on students' science interests or values. If we knew more about how and when science was being taught, we would better understand the differential, predictive power of parent and teacher expectations of children's science efficacy.

Though we set out to understand the formation of 3rd to 5th grade children's interests and expectations in elementary science in the environs of rural elementary schools in Oklahoma [largely low-SES and AI students] we were not successful in gathering enough surveys to mirror the community of interest. As it happened, this study sample included more White ($N = 102$) than American Indian ($N = 30$) children; more college educated ($N = 97$) than high-school educated ($N = 29$) parents; and more participants with income below the federal poverty line than did the participants without longitudinal data ($N = 2165$). In other words, the sample was somewhat biased away from lower-income students and American Indian students based on attrition from the survey due to transferring schools or moving. Unfortunately, though we began with a large sample size, our longitudinal results may be limited to the less marginalized children and families in this region.

Finally, we limited parent participants to those who were maternally related to the children [paternally related parents ($N = 10$) were excluded]. We do not think this response rate is unique to our population as others researchers have found mothers are the ones who fill out take-home surveys. By way of example Tandon, et al.'s (2014) study, focused on a balanced sample of 713 children, yielded parent surveys where 86% identified themselves as females.

Conclusions, Implications, and Future Research

The novel finding in the current study is that these parents had direct influence on children's achievement (over and above the influence of children's own beliefs about science efficacy) while teachers had neither direct nor indirect influence on children's expectancy for success. We are not able to explain the mechanism of action for this influence; however, it is important simply to note that the influence exists. Clearly, parents matter when it comes to elementary science achievement. Given that these research results suggest parents are more

influential than teachers when it comes to children's own expectations and achievement success in elementary science, our open-systems perspective prompts further interest in research and policies that explore a) parent expectancies and b) improve on the status-quo with regard to home-school relations and elementary science classroom strategies that help to better align the teachers' role in positively influencing children's expectancy for success.

Parent expectancies. Future research might focus on parent expectancy as a function of child ability. The current study implies that parents can modify children's science self-efficacy by encouraging them to participate in science activities outside of school. We wonder how parental encouragement of students' participation in science activities outside of school influence might be linked to children's science achievement. Future research might explore the ways parental expectations of children's science learning are linked to the parents' own educational attainment or parents' relationships with classroom teachers and school staff.

We are disappointed to realize that our research approach did not inform us about the discrete expressions of racial or gendered dynamics (Hesse-Biber & Yaiser 2003, Weisgram & Bigler 2007) of these rural, Oklahoma school communities (largely low-SES and American Indian (AI) students). Though we had AI partners on the research team and within the participant communities, we failed to establish the necessary interest or trust needed to achieve maximal parent response. Thus, we recommend future researchers (who are interested in similar populations) employ mixed-methods approaches that allow for a richer data set. These strategies might involve a variety of qualitative approaches to include training community members to lead parent focus group discussions.

Home-school relations. In rural schools, a focus on cultural relevance (Brown & Medway, 2007; Kelly-Jackson & Jackson, 2011; and Ladsen-Billings, 2009) might help

elementary science teachers depart from fact-based science instruction and begin to introduce culturally connected science lessons linked to children's specific community. Epstein's (2011) model, of the overlapping spheres of family, community, and school, educators, is consistent with our open systems perspective (Figure 1) and encourages responsive family communications that extend beyond the traditional activities (newsletters, school volunteers) as well as flexible responses to parents requests (Coleman, 2013). We expect a parents-as-partner communication model might provide important context for validating the expertise parents bring to the school relationship. We expect such a school model might help align parents and teachers' communication of science knowledge and we wonder how adult expectations would impact students' science efficacy when parent and teacher powers are more balanced. Future research might explore the ways educators incorporate opportunities for teachers to develop parent communication skills, focused on real-life applications.

Science classroom strategies. While the results of the present study point to important parental influences, much of science learning still occurs in the classroom. Improving science curricula can be envisioned more holistically to include strategies that enhance value and family buy-in. Brophy (2008) suggested a number of ways to enhance K-12 curricula to include lesson framing (introductions that explain the lesson value and model the lesson applications) and appreciation scaffolding (opportunities that enable students to apply the content and discover the lesson benefits first-hand). We note that the Next Generation Science Standards (NGSS) (National Research Council, 2012) have already reduced the mass of details to an important core of ideas in science and engineering. The next step then, according to Brophy (2008), would be to develop a new theoretical base to guide curriculum developers' and teachers' engagement in valued science learning, deep understanding to enable and encourage STEM careers and lifelong

learning. We wonder how science educators might help improve local decision-making (to include meaningful opportunities for children to explore science) as school systems interpret and implement national, state, and district policies. That curricular process could potentially improve parent and community investment and belief in science education.

Wallace (2014) reasoned successful, reform-oriented professional development is dependent upon helping teachers identify their own core beliefs. However, there is little research to confirm whether or not increased self-awareness of one's own core beliefs can affect belief change. Certainly, Haney et al.'s (2002) research encourages additional controlled studies exploring causal links between elementary science teachers' beliefs, practice, and student learning. Future studies might expand on Schroeder et al.'s (2007) regard for enhanced teacher strategies. Future researchers should also consider qualitative research to understand how students make sense of parents' and teachers' beliefs. We encourage additional research to increase and improve opportunity for rural, elementary science teachers to learn more about the link between their own core beliefs and student achievement. Efforts along this line can help to advance opportunity for children's early science learning experiences to engender later attitudes and beliefs about their own interest and abilities in science.

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