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Using Constructivist Grounded Theory to Understand Why Female Secondary Students Engage in Scientific Research

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ABSTRACT
In the United States, science education has undergone substantial reform efforts due to projections of an increased need for science, technology, engineering, and mathematics (STEM) workforce. Recent reform efforts call for students to engage in scientific inquiry through the practices of scientists and engineers. Research highlights the potential for student immersion in research and engineering practices, such as science fairs, to meet the needs of updated standards. Furthermore, groups of students that have traditionally been underrepresented in STEM careers, such as women, might benefit from science learning opportunities like scientific research for science fairs that can take place both within and outside of the typical school day. While some research has investigated student motivation using expectancy-value theory, for example, and other research has investigated students' compulsory participation, no known research has produced a theoretical model of why students choose to become involved in science research opportunities. Constructivist grounded theory is one approach that can develop theory about these motivational processes, from the perspective of the participant. The goal of this study was to theorize about female students' motivational processes when they re-engage with scientific research across grades 6-12. Data was collected through intensive interviews and analyzed using constructivist grounded theory from 21 students across eight rural and urban school districts in a Great Plains state. Findings, vetted through theoretical sampling and member-checking, yielded a theoretical model of the processes, challenges, and supports female students encountered. This study contributes to the literature on motivation to do scientific research through science fairs as findings highlight students' needs for autonomy in their research topic, students' realization of scientific research as a tool to investigate meaningful problems, and findings suggest the development of science identity. Science fairs are seen as venues where difference-making research can be divulged to the scientific community.

KEYWORDS: Grounded theory, Motivation, Science fair, Sponsor teacher, Student research.

Science learning during secondary school in the United States encompasses an array of opportunities including formal science education that is based on standards and curriculum, out-of-school time science learning that is delivered more informally such as science-talk at home, museum, zoo, and science center visits, and learning not strictly tied to standards such as scientific research. Despite an abundance of opportunities for students to engage in learning through scientific research leading to involvement in science fairs, sparse amounts of literature have investigated student motivation to voluntarily engage in these activities. Research by Czerniak (1996) found that 85% of participants in a regional science fair were required as part

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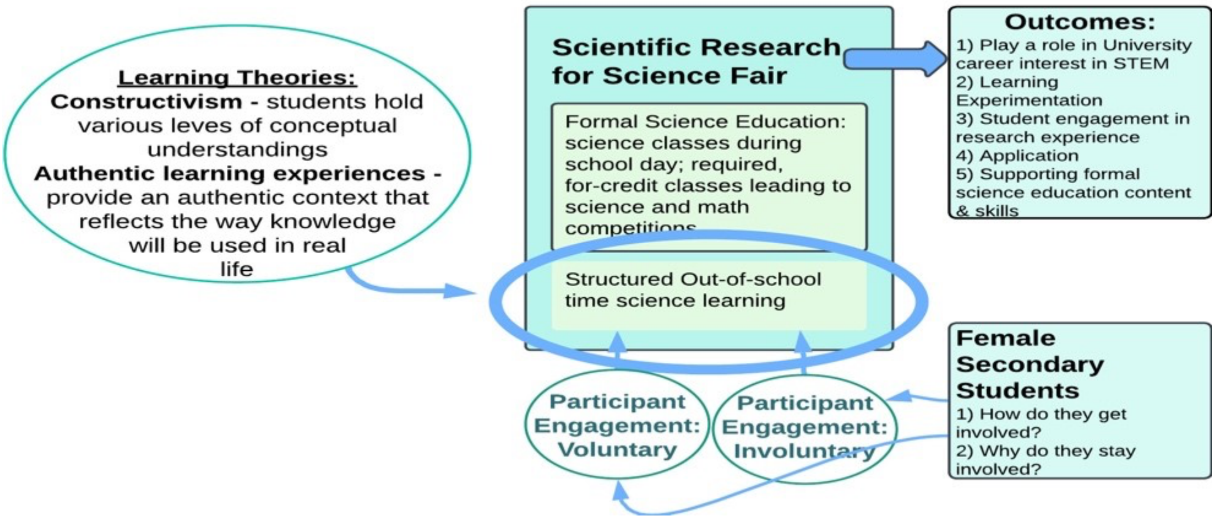
of their curriculum to complete a science fair project as part of their in-school learning. A key result from this research noted "it would appear from these findings that students were not intrinsically motivated to complete a science fair project" (Czerniak, 1996, p. 25). More recent research found that only 15% of SEF participants (59) in 2018/2019, and 18% (171) in 2019/2020 were NOT required to do science fair (Grinnell et al., 2022). We see similar participation trends from research by Dionne and colleagues (2012) when they investigated the Canada-Wide Science Fair finding of compulsory participation. There are notable learning benefits to students such as increased sense of self-efficacy, feelings of achievement and being rewarded, positive views of the social aspects of science fair, and increases in learning strategies (Dionne et al., 2012). They posited that these were important factors in students' decisions to participate. However, given that over one-third of the participants in this data set were obligated to conduct their science research projects, it is difficult to confidently relate the research findings to inquiries into student choice in participation in science fairs.

While many students' participation in science fair is obligatory, there are science fair participants who are seemingly more intrinsically motivated to conduct research and share their findings than others. Within this smaller collection of literature, very little attention has been paid to student motivation to continue conducting scientific research and present at the science fair. Recent research, for example, has reported that factors such as academic performance, interest, self-efficacy, or even prior participation (8th grade) in STEM programs failed to significantly explain high school students' participation in STEM learning opportunities (Chan et al., 2020). Empirical research is needed to gain a better understanding of the processes that guide secondary students' continual engagement in scientific research to present at a science fair. Figure 1 demonstrates the conceptual grounding of this current study.

Figure 1
Conceptual Framework – Scientific Research as an Opportunity to Learn



Literature Review

How Do Students Engage in Scientific Research?

Science fair is a primary venue for student engagement in scientific research, either voluntarily or compulsory for a grade or to meet the requirements of a specific program. Scientific research is presented to peers and a panel of judges who hail from various backgrounds, including content experts and science researchers. Science fairs occur at various levels, for example, school, district/region, state, and several options for terminal-level fairs such as the International SEF (ISEF), or the American Junior Academy of Science (AJAS).

Students may or may not compete against one another for awards, placings, and/or advancement to a higher-level fair. Science fairs are often acknowledged as venues for which students will engage in hands-on scientific research (Bellipanni & Lilly, 1999). Currently, science fairs take place in 47 states across the United States, involve a range of learners from 9 years old to seniors in high school (DeLisi et al., 2021), and even include college undergraduates who present research that they conducted in high school.

Contextualized Understanding of Science Fair

SEF participation varies in the compulsory or voluntary nature of SEF interaction (Grinnell et al., 2018). In a study of middle school science fairs, research results showed that only 20% of participants did so voluntarily, with their research projects having very little explicit connection to formal curriculum (Kook et al., 2020). SEF participation shows considerable ethnic diversity. According to one study of high school SEF participants across seven states, Asian students made up 32% of the population, Black students 11%, White students 33%, Hispanic students 20%, and Other students 3% (Grinnell et al., 2022). Although ethnic diversity varies based on several factors, including region, urban status, etc.

Students Face Challenges When Conducting Research

High school and post-high school students encounter obstacles while engaging in scientific research. Research findings show that time, resources, and developing an investigable idea are frequent obstacles, in addition to getting unexpected results, organizing research efforts, and general motivation to do the project (Grinnell et al., 2017). Science fair participants cited strategies to overcome their struggles, such as doing more background research, making timelines, or altering the research plan, and persevering through difficult times. Saw and Agger (2021) note that, compared to their urban counterparts, rural students may experience different levels of access to science learning due to geographical remoteness, such as fewer STEM extracurricular programs, math and science course offerings, and teacher capacity. Mentoring and support were additional barriers, as Kook et al. (2020) found that in schools that required science fair participation and served more African American students, the students were more likely to receive low levels of support.

Positive Outcomes

Scientific research experiences can provide leverage to break out of the secondhand, confirmatory science practices that remain common in U.S. schools. Dabney et al. (2012) posit that viable science education includes participation in: science clubs/camps; science and/or math competitions; engagement in personal science hobbies; reading and/or watching fiction and non-fiction science; and playing computer/video games. These experiences can be advantageous toward improved learning outcomes for students (Grinnell et al,, 2017), especially when connections can be made that are personally relevant to the learner (Vennix et al., 2018). Chitum et al. (2017) found that after-school programs, such as science research clubs, were an effective way to maintain middle school students' motivation and interest toward science learning. Further research suggests that STEM experiences deepened science content learning (Ozturk & Eren, 2020; Roberts et al., 2018), learning about experimentation (Paul et al., 2016) and inquiry (Schmidt & Kelter, 2017), had positive effects on post-secondary matriculation (Sahin, 2013), could lead to increases in students' interest in science and engineering (Grinnell et al., 2025), although no significance difference between male and female increases in interest, and provided opportunities for students to apply science processes and content to learning (Andersson et al., 2021).

Women in STEM

Women continue to be underrepresented in science fields, including senior positions within the field, across many countries (Larivière & Sugimoto, 2017; Sugimoto & Larivière, 2023). There is a gender gap that largely pervades many STEM and science fields in research produced by women, at least partially due to unacknowledged contributions of women (Ross et al., 2022), that might be partially responsible for women's attrition from the field (Huang et al., 2020). Despite the gender gap, research findings suggest the inclusion of women on scientific teams including higher proportions of women on research teams increases collective intelligence, and the potential for the intentional development of scientific teams inclusive of women can give opportunity for their contributions to be expanded (Love et al., 2022).

Many sponsor teachers and regional initiatives are now focusing on supporting you females through the STEM pipeline. The Walking Mountains Science Center developed programming to help girls to see themselves as scientists, engineers, and mathematicians while they are in grades 3 through 5 (Girls in Science as a Pipeline to STEM, 2023). Other research notes the moves sponsor teachers have made to focus on supporting female students (Andersson et al., 2021, Schaben et al., 2022). These strategies and programs, in addition to other factors such as the Girls in Science Initiative (Girls in Science Initiative, 2025) covering grades 4-12, might be helping to close the persistent STEM gender gap (NSF, 2019) that may start as early as 1st grade for engineering and computer science (Master et al., 2021).

Why Students Choose STEM

Several key models from current literature help explain why students may be interested in STEM careers and choose to major in STEM degrees. Science identity and expectancy-value theory are leading theories that provide important insight into students getting into and staying interested in STEM, although there are many factors that contribute to attrition from STEM education and STEM careers, which I will discuss later. As previously noted, the literature on why students choose to do scientific research for science fair is very thin, particularly related to why female students choose the field; however, as science identity and expectancy-value theory cover STEM interest, in general, they should be further investigated in relation to motivation to do science research for science fair.

Development of a Science Identity

Science identity has been strongly linked to students choosing STEM careers (Carlone & Johnson, 2007; Hazari et al., 2020) and could be differentially more critical to develop a strong science identity in girls (Vincent-Ruz & Schunn, 2018). Students are said to have a strong science identity when they see themselves as scientists or can understand themselves as a person of science (Gee, 2001; Kane, 2012). Carlone and Johnson (2007) consider science identity to consist of three constructs: science performance, science competence, and science recognition.

A central aspect of the development of science identity occurs when a student is recognized as a science person. For example, students who are recognized for their work in the discipline of physics may develop a physics identity (Carlone & Johnson, 2007; Hazari et al., 2020). Dou et al., (2019) note that recognition is a complex construct, as recognition might be self-recognition in one study while other research is measuring recognition by others. Although defining multiple aspects of recognition might be problematic, it may still play a role in the formation of science identity, as research findings indicate various types of recognition as contributing to gains in science identity (Hughes et al., 2021). For example, in their study of female students doing coding, a student who was recognized by educators (but not by peers) for her competence showed an increase in the strength of her coding identity due to her perseverance through increasingly complicated tasks. Conversely, another student who was frequently recognized by both peers and educators as having skill in all aspects of coding saw her coding identity grow stronger, as well.

Other research has noted important connections between STEM interest and identity. For example, one study indicated that a diverse group of students who participated in environmental science programs developed an interest that enabled them to see themselves as science people (Carlone et al., 2015). A similar qualitative study found the development of interest in art and science to foster science identity in a female middle school student (Calabrese Barton et al., 2013). More recent frameworks, such as those used by Dou and colleagues (2019) focused on just STEM recognition and STEM interest. This limited scope resulted from extant findings and evidence indicating these two constructs are consistently linked to the development of math and physics identities (Cribbs, 2015; Hazari et al., 2010; Hazari et al., 2020).

Interestingly, research by Dou et al. (2019) demonstrated that informal K-4 science experiences, such as science clubs and science competitions, did not predict STEM identity development, but that everyday experiences, such as talking about science, were linked to students' more positive STEM identities. This relationship was found to be significant irrespective of science capital, despite research findings by DeWitt & Archer (2017) that young people are more likely to have informal science experiences if their parents work in science professions or if the individual is a high performer in science class. This suggests the power of informal and seemingly simple interventions that have supported the development of STEM identity for students from diverse economic backgrounds. Taken together, findings from these studies suggest STEM identity development that occurs in STEM clubs and competitions is limited to upper elementary and secondary school, rather than at the K-4 band or below.

Expectancy-value theory (EVT)

EVT has been used to help understand and predict high school science achievement, college persistence, and choosing to major in STEM disciplines. EVT seeks to explain achievement-related choices based upon personal or efficacy expectations (Eccles & Wigfield, 2002). Any task an individual may choose has both positive and negative characteristics that affect engagement in the task, and each choice that is made has associated costs and benefits. An individual's expectancy for success and value of the task or outcomes of the task influence choices to engage in the task, then, and even performance in and persistence through the task. Task-value has four measurable components: attainment value, intrinsic value, utility value, and cost (Eccles et al., 1983). Importantly, work by Eccles and colleagues has found that individuals' broad beliefs about competence in any field are empirically analogous to expectations for success on a specific task within that field (Eccles & Wigfield, 2002).

Perez et al. (2019) identified three motivational profiles in undergraduate chemistry students at a private college, based on levels of science expectancy, value, and cost beliefs. Findings indicate cost beliefs vary across levels of expectancy and value. For example, high expectancy/value beliefs were correlated with lower cost beliefs. Research findings indicated no significant interaction between gender and motivational profile. Overall, this research suggests connections between motivational profiles and collegiate STEM outcomes. For example, students who belonged to lower-level motivational profiles had lower STEM achievement than did members of higher motivational profiles.

These findings make important contributions to research evidence examining motivation in science, and they also support prior work in EVT showing that students who have lower science expectancy-value beliefs have relatively low STEM achievement and persistence. The link between low EVT and lower STEM outcomes seems intuitive. However, some contrasting research results suggest that there is a need for research that can provide a more holistic context and description of motivation in STEM. This is despite the presumption that expectancy-value beliefs "mediate the relations between contextual factors and academic and career choices" (Perez et al., 2019, p. 269).

Grounded Theory

Glaser and Strauss (1967) pioneered the qualitative research approach labelled grounded theory (GT) to investigate phenomena in which there is no existing theory – this contrasts with most other styles of qualitative study (Merriam & Tisdell, 2016). The focus of this study was to build a theory of substance – an understanding of the process of female secondary students' involvement with scientific research that is rooted in the everyday world and that can be used in practical application. Creswell & Guetterman (2019) describe grounded theory as a move from just a description to the generation or discovery of a theory that is grounded in data from direct participants of the experience. Grounded theory is well suited for this study for its ability to investigate patterns and relationships among the 6 Cs of social processes: cause, context, contingencies, consequences, covariance, and conditions (Glaser, 1978; Strauss & Corbin, 1998).

Constructivist Grounded Theory

As Birks and Mills (2015) note, grounded theory methods (GTM) now depend upon the clarification of the interaction between the researcher and the participant, based upon epistemological beliefs. Therefore, differences between Glaserian, or Classic, GTM and Constructivist GTM are housed in what the researcher believes about the nature of knowledge, and the role that research participants may play in the development/discovery of knowledge. Bryant (2019) noted that Constructivist GTM has taken the 'interpretive turn' to developing and continuing a discourse between data and researcher. Further, the position of reality moved from being a static thing, absolute, something to discover, to 'reality as experienced by the reviewer' (Clarke et al., 2016). Finally, contextual situations matter and are not discounted or "generalized out" of the findings.

Constructivist GTM primarily uses two forms of coding: initial coding done word-by-word, line-by-line, staying close to the data throughout, looking for tacit assumptions, and focused coding that identifies initial codes that appear frequently; and focused codes, which are the results of emergent processes that result in the re-organization of the data while the theoretical importance of codes emerges through analysis (Charmaz, 2014). During comparative analysis, these codes are determined to have analytical power, and therefore, focused codes become more conceptual (Charmaz, 2014; Walshe et al., 2025).

Constant comparative analysis, along with theoretical sampling, are cornerstones of grounded theory and are generally conserved across GTM. Constant comparison was introduced by Glaser and Strauss as an iterative process between data collection and data analysis (Bryant, 2017). The researcher compares data to data; compares across statements and actions of interviews to actions and statements of other interviews; compares earlier to later data in an interview; and compares observations temporally and geographically (Charmaz, 2014).

Constructivist grounded theory is an appropriate approach to inquiry involving social justice issues (Keane, 2025), such as equitable opportunities to participate in scientific research for female students, despite being the "road less traveled" by many graduate students (Finley & Howard, 2024). Prussing et al. (2024) note the flexible capacity of constructivist grounded theory to embrace ways of knowing and asking different questions being a benefit to uplifting unheard voices. This aligns with the work of Pratt et al. (2023) innovations in a person-centered constructivist grounded theory approach, and research outlining the appropriateness of constructivist grounded theory as a tool to investigate student experiences (Layton & Gerstenblatt, 2022).

In summary, Charmaz (2014) notes that grounded theorists advantage the sometimes strict, and explicit set of guidelines that assist the researcher in proceeding through the development of theory. Grounded theorists also benefit from the modifiable nature of grounded theory, making it receptive and responsive to new data (Clarke et al., 2016). These characteristics will be most beneficial in conducting a robust study with the added benefit of the flexibility that may be required in creating meaning through data collection and theoretical sampling. Constructivist ground theory is well-positioned to give voice to my participants in its person-centered approach. Grounded theory will help to uncover how participants respond to the conditions and changes in the conditions (Corbin & Strauss, 1990) that accompany being involved in scientific research for science fairs.

Case and Methodology

Purpose of the Study

The purpose of this constructivist grounded theory study was to investigate the processes through which secondary students choose to engage in scientific research leading to science fair participation. I collected data through semi-structured participant interviews and analyzed using a constructivist grounded theory approach. This approach relies upon the co-construction of understanding of this phenomenon. Data from this study yielded a theory to help explain student involvement in these science learning opportunities. An understanding of how students engage and remain engaged in science research has broad implications for educators, both formal and informal, school systems, and professional organizations. This contribution to the science education literature will help guide stakeholders in efforts to include more learners and keep them involved in this type of science learning, especially those who have been underrepresented, such as women and minorities, in science learning opportunities. This could lead to the engagement of science students in the type of science learning called for in rigorous science standards, an increase in science content and skill expertise, and maintaining interest in STEM education and careers.

Researcher Positioning

During data analysis and subsequent interviews, it was crucial for me to maintain the position that participants hold the answers to the research problem (Creswell & Poth, 2018) and to be cautious about tabling meaning that was brought to the interviews and data analysis. At the same time, I needed to be cognizant of the interpretative nature of the constructivist approach, namely that meaning will be made through my interpretation of the interview data (Charmaz, 2014).

My own experiences with science fairs range from participation as a student in high school to being a judge for school-level, local, regional, and state science fairs. I have co-sponsored after-school science research clubs, directed school-level science fairs, and co-developed and ran an intensive student science research development program for approximately twenty high school students. Finally, I have served on the board of directors of a regional science fair. As such, my personal belief is that scientific research for science fairs can have wide-ranging benefits to those who have the opportunity and interest to participate. I also understand the commitment and workload inherent in these experiences, which is why I prioritize questions about what draws students back to engage in these types of activities, especially when done not-for-credit, outside of the school building.

Research Questions

Central Research Question

What processes motivate female high school students to stay involved in out-of-school time scientific research leading to science fairs? Table 1 provides a breakdown of specific sub-research question.

Table 1
Research Questions

Research Question	Data Sources	Analytic Method
What specific challenges do female students encounter while completing their research and preparation for entrance into a science fair? How do participants meet these challenges?	Participant Interviews + literature	Constructivist GT
What social processes, including peer and family support, encourage continued student involvement?	Participant Interviews + literature	Constructivist GT
What are the main implications (outcomes) from these experiences?	Participant Interviews + literature	Constructivist GT

Ethical Considerations

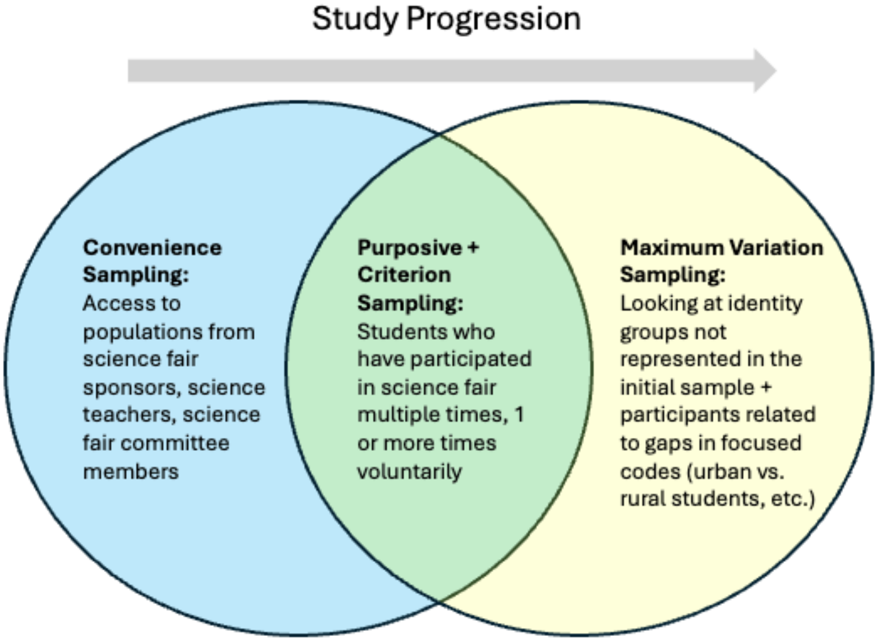
This study followed ethical procedures including privacy of participants, de-identifying data, and was approved through University of Nebraska-Lincoln IRB # 20180518112EX.

Participant Selection

Qualitative inquiry requires sampling that will appropriately represent the phenomenon of interest through interviewing, observation, and examining documents, etc. (Morse & Clark, 2019). The pacing and flexibility of sampling is one of the critical aspects of qualitative research, as sampling can be thought of as a longitudinal process, taking place across the life of data collection and analysis in a study. Morse and Clark (2019) note that sampling is a key to rigorous research, an idea also supported by Guetterman's (2015) conclusions that rationale for sampling decisions should be included in research reports.

Criterion and convenience sampling were used to sample from a pool of recent (past three years from 2018-2019) participants in a local regional science fair in a major metropolitan area, see Figure 2. Criteria included voluntary participation in science fairs on at least one occasion, with participation in two or more science fairs. There were no initial selection criteria for differences of socioeconomic status, ethnic backgrounds, or other demographics, however, the initial sample consisted of an ethnically diverse group of female participants. Convenience sampling took place via my access to participants through science fair sponsors and word-of-mouth about this research. During the second round of data collection, I expanded the participant pool based on theoretical sampling to be more representative of the state discussed in further detail below.

Figure 2
Sampling Methods Throughout the Study



Demographics

20 female participants, predominantly White (15), Indian (3), and Latina (2) participants were interviewed for this research. At the time of their interview, all participants had engaged in science fair within two years and all but one were interviewed during a science-fair year. Interviewees hailed from eight public school districts representing 12 schools across a Great Plains state.

I did not collect traditional socioeconomic status data for this research. However, I did examine the level of science capita (that is, STEM-oriented resources available to the participants within their family social context) that participants reported within their respective families. Eight participants were from non-science backgrounds, and 9 came from a science background, with a small handful unknown. This measure is an estimate based on self-reports of parents or siblings who work in STEM fields, or exposure to science-oriented activities (e.g., snorkeling and diving ocean reefs) that influenced participants' interests. This description did not necessarily speak to the amount of direct family assistance (e.g., hands-on help or other direct assistance with the actual science project and materials, etc.) each student received in their research endeavors but functioned as a description of a key aspect of the broader socializing context present in the family ecosystem. Participants' interview responses regarding these resources are discussed in further detail in the sections below.

Table 2

Measure of Science Capital: Familial Connections to the Sciences

Pseudonym	Science Background	Unknown	Non-Science Background
Aisha	Mother and father		
Belinda	Father science teacher		
Bethany	Mom science teacher, 4H		
Britney	Summer trips diving/snorkeling		
Valaria			Father science interested, but not his background
Catherine			Grew up “outdoorsy”
Marcy		X	
Tina		X	
Anna	Grandmother interested in plants and flowers, cousin wildlife conservation		
Moni	Sisters are physicians		Parents supportive
Eileene			Mother English teacher, father pastor
Jessup			Family helped a lot
Allie	Father a physician		
Sondra			Parents supportive
Dalva		X	
Mava			Parents pushed her to do science fair - but not science professionals
Senna	Mom and Dad computer engineers		Parents pushed her to do science fair - but not science professionals
Halsie	Dad IT and computer science		
Sereta			Ranchers
Lilian	Father science teacher		

Theoretical Sampling

Research approaches must be flexible enough to allow for concepts and theories to emerge. Theoretical sampling dictates the direction of iterative data collection (Charmaz, 2014) to discover this meaning, contributing to the development of a middle-ground theory (Morse & Clark, 2019). It is important to note that theoretical sampling might entail a generation of new participant data, but also renewed glimpses into data from current participants, data from primary research reports, and/or data from other academic literature (Draucker et al., 2007). Birks and Mills (2015) define theoretical sampling as “the process of identifying and pursuing clues that arise during analysis in a grounded theory study” (p. 68), while Charmaz (2014) more precisely defines it as pertaining “only to conceptual and theoretical development of your analysis” (p. 198). Other theorists, such as Draucker et al., (2007), present a similar perspective and simply state “…theoretical sampling is guided by emerging theory” (p. 1137). For the purposes of this research, I consider theoretical sampling to have taken place after initial data collection, sampling that was guided by the development of theory.

I engaged in theoretical sampling several times during the constant-comparative analysis of this study (see Figure 3). For example, previous research findings note that although “science and engineering entrants come from rural communities as well as urban areas...rural students usually become interested in science projects as a way to help solve real-life problems...” (Decker, 1984; as cited in Bellipanni, 1994, p. 3). Data taken directly from my research suggested “solving real-life problems” as an important facet of student decisions to engage in scientific research for science fairs. The initial sample of participants came from a large metropolitan area, so it was necessary to use purposive criterion sampling to include students from more rural locales. An additional eight participants were selected from rural areas, representing three schools in three different school districts. In addition, data analysis and prior research findings suggested a resource availability issue for rural and urban students. I resampled from interviews in my own data and adjusted interview prompts for upcoming interviews to gather data related to experiencing and overcoming resource deficits.

I collected data were through semi-structured, intensive interviews of participants through the iterative process of conducting constructivist GT (Charmaz, 2014). The semi-structured interviews were guided by an interview protocol (see Appendix A), and took place either in person or through Zoom. To ensure the safety of participants, in-person interviews were conducted in an area of participant selection, such as local public libraries. For interviews conducted through Zoom, meeting links were emailed to participants, and their parents if under the age of 19, and secured meeting rooms were used. Interviews lasted between 20 and 30 minutes initially, and for follow-up questions related to theoretical sampling, I emailed questions to the participant to answer. Interview audio for in-person interviews and audio/video for Zoom interviews was recorded and then transcribed using secure transcription services such as Temi.com. In accordance with safety and IRB, transcripts were de-identified. I read and listened to the interviews to ensure accurate transcription of the audio and then memoed about them. These steps supported my goal of staying close to the data (Charmaz, 2014).

Theoretical Saturation

Morse and Clark (2020) provide several criteria if saturation is not reached, as can happen due to limits of time, funding, and other resources, it is important to understand the gaps that might be present in the resulting theory and to discuss these gaps in the paper. While work by Guest et al. (2006) noted saturation of codes after just 12 interviews in their GT study of sex workers in West Africa, suggesting that saturation may be reached with minimal research participants, although grounded theorists seek saturation of categories, not of data or codes (Charmaz, 2014). What's more, theoretical transference – the ability of the researcher to illustrate application of the theory beyond the initial contexts of the study (Morse & Clark, 2020) relies upon a full conceptualization of saturated analysis. I considered theoretical transference carefully when deciding when to cease data collection and analysis.

Thus, the difference between grounded theory theoretical saturation and saturation in other qualitative methodologies is the focus is on saturation of categories and higher-order analytical themes, rather than simple saturation of data (i.e., getting the same/similar data in subsequent interviews). The key difference is that saturation is determined at a different analytical stage. It was difficult to precisely note when my categories became saturated, as the categories filled out at different rates. Some categories, such as "realizing success at science fair," developed relatively quickly, within the first 10-12 interviews, while categories like "CHOOSING to do science fair" did not reach saturation until nearly all interviews were completed (~20 interviews).

Data Analysis

Role of the Literature

Withholding an in-depth literature review until the near conclusion of a grounded theory study is often erroneously attributed to Glaser and Strauss (Nathaniel, 2022). Morse and Clark (2019) suggest a pitfall for many grounded theorists is neglecting to sample the literature to ensure the uniqueness of a study. Consulting the literature serves to discover allied theories/concepts are similar yet different from another researcher's (your own) work. Failure to do so can result in 'theoretical congestion' (Morse, 2000) – the existence of many similar theories, often of weak generalizability because they have not been synthesized with each other. More recently, Hadley has recommended an approach where the researcher will conduct level 1 (initial) coding, followed by level 2 coding (focused) on just a few data sources prior to consulting the literature (G. Hadley, personal communication, April 12, 2021). Following the literature review, the researcher then codes the remaining data, aligning with Thornberg and Charmaz's (2014) constructivist approach of "knowing and using the literature". This method supports abduction in that relevant literature may be used as possible lenses to view the analysis. For this study, I delayed an in-depth literature review until after initial coding was completed for the first three interviews (G. Hadley, personal communication, April 12, 2021).

Coding

Two primary coding schemes were used during the open coding phase: _In Vivo_ coding and process coding. _In Vivo_ codes, using the participants' own words and socially relevant phrases, naturally fit the data set (Charmaz, 2014). In Vivo codes allow data analysis to take place in the participants' contextual space. Process codes, identified by Charmaz (2014) as particularly useful for constructing grounded theory, use gerunds – verbs+ing. This method allows for a description of the individual's process and actions rather than labeling the individual (Saldaña, 2021). I used _In Vivo_ and process coding through initial and focused coding, and several of these further became conceptually relevant to my research questions. An example of an _In Vivo_ code that was elevated in conceptual status is "Personally Meaningful", referring to the importance of the work science fair students did. An example of a process code is "Realizing Success at Science Fair". This code was also elevated to the level of category as the data suggests some aspect of success is critical to students' processes of choosing to do the science fair.

Literature was consulted to research findings on students' motivation to engage in science fairs took place between the phases of initial and focused coding. Additionally, the literature review served to enhance my theoretical sensitivity (Birks & Mills, 2015) in that I was able to gain a greater understanding of these established concepts both in extant literature and to more fully understand how data for this study. For example, findings from initial coding suggested that students developed a membership in the scientific community through science fair participation. This led me to literature on Science Identity, and proposed mechanisms for student development of science identity.

Focused coding followed the literature review. According to Charmaz (2014) "focused coding means using the most significant and/or earlier codes to sift through large amounts of data. Focused coding requires decisions about which initial codes make the most analytic sense to categorize your data incisively and completely" (p. 57). This method allows the researcher flexibility in their analytical approach by being open to the potential theoretical significance of several codes.

The remainder of the data were then coded using the 13 focused codes developed in the previous step. At this point of the analysis, core categories often emerge from the focused codes, as was the case with my research and when engaging in constant comparison. Comparison of codes to categories and categories to categories within and across participants further develops, delimits, and refines categories (Thornberg & Charmaz, 2012). During data analysis, I wrote memos about each code, revealing relationships between codes, which I further explored with tools such as theoretical sampling of already-collected data, literature, previously interviewed participants, and new participants to identify the boundaries of the categories.

Some grounded theorists advocate for using theoretical codes to "weave the fractured story back together" (Glaser, 1978, p. 72). While Charmaz notes that theoretical codes might be helpful to identify relationships between categories, this process, as prescribed by Glaser (1978), involves the import of pre-existing ideas that largely hail from extant theories (Thornberg & Charmaz, 2014). For this reason, I did not engage in theoretical coding but instead opted for another abductive method of developing models grounded in the data of this study and testing them against the data. Grounded theory, by nature, is an abductive method, and these methods are closely linked to the theoretical sampling that took place.

Memo-writing

Constant comparative methods, such as memo-writing (Glaser & Strauss, 1967), are integral to the construction of grounded theory (Charmaz, 2014), having been identified as "the cornerstone of quality" (Birks & Mills, 2015, p. 39). Memos develop in conceptual complexity as data collection and analysis progress. For example, memos during open coding might be more concise and exploratory than focused-coding memos (Thornberg & Charmaz, 2014), as memos during focused coding can be used to elevate codes to conceptual categories by defining the category and exploring its properties. I engaged in memo-writing after each interview concluded, during initial and focused coding, while reviewing relevant literature, throughout conceptualization of theory, and about research processes. I utilized a more structured memo-writing scheme throughout focused coding, thus raising the analytical level of my memos. This involved writing memos for meaning, action, challenges, and results (MACR) (Hadley, 2017) to fully develop code categories and allowing memos to interact with data and extant literature.

Findings

Several major themes emerged from data analysis in my study, leading to the development of a theoretical model.

Challenges and Mediation

Students navigated their participation in science fairs through multitudinous challenges due to the support they received. Most study participants struggled with aspects of their research design and confounding results ("doing science"), and with resources such as time, materials, and expert assistance. Many of these challenges align with findings from extant research. Results from the work of Grinnell et al. (2017) suggest that students encounter time and resource obstacles, as well as the challenge of getting unexpected results from their research. What's more, rural and small-town students, who made up approximately one third of my research participants, may face comorbid challenges with fewer opportunities to access rigorous STEM learning opportunities (Saw & Agger, 2021) besides the challenges of access to resources and inconclusive results.

Table 3
Challenges – Examples from the Data

Student	Challenge	Quote
	Experimentation	
Addie		"had a lot of failure in the beginning", because "my doses ended up being way too high"
Hafsa		"keeping my variables constant" was difficult

Mava	"actually figuring it [how to set up the experiment] out was the hard part."
Costs/resources	
Ana	"it just costs way too much to get them [flies] genetically modified [with gene of interest]."
Moni	"my research projects…they're like more simple ones. I don't need giant machines that separate different parts of the cell."

Family Support

Student researchers were supported in their research endeavors by their parents, and this came not only in the form of direct assistance and sometimes even pressure to do the research, but also student-identified exposure to science, which might have fostered content interest for the student and aligns with the work of Dabney et al. (2013). Typical assistance with the project aspect of research is demonstrated in quotes from Samantha who divulged "my mom would drive me to Walmart [to] pickup materials whenever I needed," and Allie's mother who "helped to prompt my data collection for a month and a half by getting up with me every 6 hours to collect data." Parents and families were identified as being supportive of the research process, and no findings from this study, despite being sampled for, found negative cases to suggest unsupportive or even detrimental experiences with family members (or with peers, for that matter). This is not to suggest the non-occurrence of these instances when students do scientific research, just that these were not identified for this group of participants.

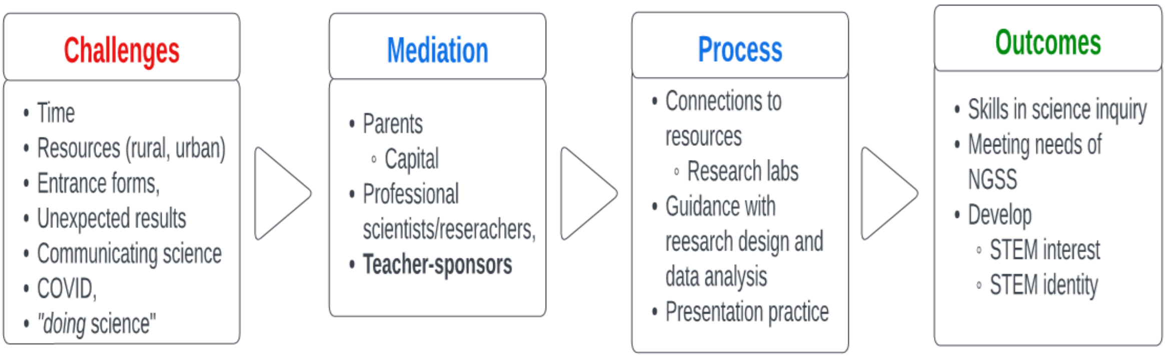
Sponsor-teacher Support

While several participants identified key support from their parents, sponsor teachers were more widely hailed across all participants as providing support for them during science-fair research. These findings parallel research findings from Schaben et al. (2022) about the importance of mentorship, particularly from a teacher, on student research experiences. Supports included access to resources and expert guidance, as was the case for Lillian when her science teacher "was able to get me into a [University] lab" as a middle school student to complete her research. This experience not only provided elite access to resources, space, and expertise, but the experience also proved important to Lillian's trajectory as it "showed me a career and not just an after-school activity." Halsie's experience highlights the motivational support of sponsor teachers, "…who keeps me involved in science fair is most definitely my teacher or coach. Without them helping me through every breakthrough and manage my frustrations I would probably not have stuck with doing science fair."

Professional Support

Some study participants' research endeavors were supported at the collegiate level by professional researchers, and at the level of industry by professional scientists. However, this interaction was almost always mediated by teacher/sponsor. Eileen provided insight into this dynamic by indicating her "sponsor teacher helps us to reach out to professors." Allie is another example of being able to access experimental setups that included staphylococcus since "a professor at [university] Dr. N. provided the staph for me…and a lab to work in". In general, student researchers were able to receive support and resources from professional scientists in ways that ranged from having their questions answered via email to directly working in the researchers' laboratories.

Figure 3
How Challenges Were Mediated



Success at Science Fair

Many SEFs host prizes for student researchers, such as cash awards, trophies/medals, certificates, scholarships, etc. Students interviewed for this study identified these outcomes at various stages of their science research adventures. For example, several students placed first or won their category at one or more science fairs, such as Aisha, Eileene, and Serese. A few participants specifically cited the importance of placing highly during their first science fair such as Belinda who noted that "…I am very externally motivated and feel successful after winning awards." Valaria noted that she, "won my school science fair, and I was excited. I'd never won anything like that." Alia earned a purple ribbon at the school science fair and then entered the local regional fair, where she placed 2nd overall. Alia was motivated by the potential to have even greater success, saying, "I thought the top place trophy looked pretty cool, and so I was like, I'll get one of those next year." Other times, however, participants' projects were judged to fall outside of the winner's circle – this was the case for Senna and Lillian, among other participants. Lillian "ended up with a participation certificate" and "did not win at all" and Senna did not win across 6th through 8th grade science fairs yet both continued to participate.

There are, however, implications for the awards, meaning more to acknowledge student work than they do as material goods. Valaria noted that, "I think the awards play a really big part of helping a lot of [my] confidence, made me realize that I have the capability to do these big things." There may be an interplay between these acknowledgements and the development of students' science identity. Finally, many students saw the point in the process rather than an award for the product, as Eileen eloquently stated in a theme that transcended many of my interviews. "Winning some prizes, which is fun, but it's not the most important thing. Obviously, it has more to do with the knowledge gained."

Developing Skills and Confidence

As one might expect, students saw positive development in their science research skills. For example, Lillian grew more skilled in lab procedures. Increases in skills and in understanding content led to increased confidence for students. Mava "learned a lot of problem solving and critical thinking skills from it [science fair]," as did Jerzie. Addie related that in prior years' projects she did not fully understand the topic, but as she has continued research, her projects have become more advanced and so has her understanding of the content and the research. Anna’s data make clear the connection between developing skills and gains in confidence. She developed a deep understanding of science content related to her research on Drosophila, and she “felt more confident in what I was doing because I’ve spent so much time learning about the specific things I did this year.” Valaria notes being successful at science fair because of her confidence, she said although “I was a very shy student, but science fairs were where I thrived because I knew my work and my yearning to share my expertise overcame my timid nature.” She poignantly noted “I did my experiment, I did my work, and that’s something I should be proud of whether I won or not.”

Personally Meaningful

Personally meaningful became a higher-level theme through the initial and focused coding of gerunds and in vivo codes such as: "enjoying science" (gerund), "meaningful challenge" (*in vivo*), and "it feels like you’re making a difference" (*in vivo*). Participants’ research topics, such as health issues, water issues, and other environmental challenges were personally interesting and became personally meaningful to them. For some, their topic of research became something they wanted to pursue in college. This interest was uncovered through their research experiences, and for many participants, the desire to do research was more important than the specific research topic. Participants took action to solve relevant, meaningful problems. This opportunity was made available through doing scientific research, and they then communicated their meaningful work and received feedback on it from the scientific community.

Enjoying Science

Unsurprisingly, students reported the enjoyment of science as a subject and noted their enjoyment in scientific research. Mava has “…always been into science, the whole world is made of science”. Marcy said she “really liked science but had never done research before” and she “liked animals so much because I would always watch nature documentaries.” When asked why she chooses to engage in science research for science fair, Aisha proclaimed “Because I like science research, I think it’s fun.” Jerzie noted “I like research. I like reading and learning about new things.” Britney’s quote nicely summarizes “in science, you don’t want to learn things you already know.” Their research experiences were meaningful because they enjoyed doing and learning about science.

Meaningful Challenge

Sereta embarked on the challenge of improving real-world aviation and, stumbling along the way, asked herself, “Where can I go with this? What can I do to improve this [problem of propeller pitch]?” She “spent three months teaching myself Solid Works Drafting and Design” to create her own propellers to test. While Sereta rose to the challenge of improving a problem in aviation, Bethany noted the challenge in confronting societal norms through her research that examined male vs. female versions of Legos. She noted her research was “pretty fun to do cause I like challenging gender roles.” Quotes from Marcy and Britney show how meaningful it is to solve a complex problem. Marcy noted “applying what you already know to figure out something that you really want to know” and “…you’re building off of it constantly.” Britney says, “the point is to have the question to figure out what’s actually happening and come up with a new answer.” Finally, Lillian notes the meaningful challenge of conveying research to an audience “you see something happen and then you get to figure out how to tell other people about it.” Her intuitive statement supports a connection between students experiencing “a meaningful challenge” and their “getting to be the expert” as discussed in the next section.

Getting to be the Expert

For students, the science fair was the venue that hosted their “getting to be the expert” experience. This code was initially derived from participants such as Britney, who said, “I really like coming here [science fair] with a project and telling judges about it…” and Bethany, who spoke about talking to people “I like teaching them, that was very rewarding, and I like that, and wanted to do it again…I love talking to people about it because I know what I’m talking about.” Aisha also presented a good example of this theme when she said, “I think it’s interesting to have people learn about that [her research topic].”

Paving the Way to my Future

Most participants came to see the value of their experiences specifically related to future education and careers through their participation in science fair. A recurring theme was how taking their scientific research to science fairs would bolster students’ resumes and would increase the impact of college applications, as relayed by Jerzie, Addie, Hafsa, Valaria, and others. For example, Bethany noted, “I’ve always kinda been college driven ever since I knew what college was, science fair [became] a tool to help get there.”

For other students, such as Lillian, Eileene, and Britney, the research led to cognizance of future careers in science. Lillian’s sponsor teacher set up the opportunity for her to work in a university research lab, and through this experience Lillian saw something, “bigger than science fair,” and it “showed me a career and not just an afterschool activity.” Eileene explained how her exploits might be useful in her future as she “discovered I have some skills in different components of research that I could probably us in the future for a career.”

It Feels Like you are Making a Difference

Perhaps most importantly, the research students were doing was personally meaningful because it allowed them to feel like they were making a difference. Anna said about her research, “It feels like you’re making a difference, even if it’s really small, you found something that means something, you know, and that’s probably my biggest takeaway.” Catherine researched local soils and surface water runoff in back-to-back science fair years, both of which ended up being meaningful to her and to the local community.

Sondra, who was not particularly interested in a science career, sought out science research experiences to highlight her resume for college, and "saw there is, even in my own community, a lot of plastic pollution so I went down the route of well, how can we fix this?" She said presenting her research, "…also helps spread awareness because I'm trying to solve an issue. It's not really just gaining resume materials, it's more of like actually making an impact on the world." For Sondra and others, the results of her research helped to make a difference, and when she took that research to science fair to share the results with others, she was able to spread awareness about the issue and was the expert in that moment regarding her topic.

However, two extreme cases should be mentioned, that of Mava and Catherine. These students reveled in the limelight of being on stage. Mava stated, "I love to be [in] the spotlight and perform, and like have everybody looking at me, so it was great." Mava did enjoy being the expert on her topic, but above and beyond that, she enjoyed the performance aspect. Catherine's case was very similar to Mava's. Catherine said, "I just like to talk, I can talk about anything." Gaining skills and knowledge about her research through the research processes was another opportunity for Catherine to converse with others. While this sub-category certainly does not accurately depict the experience of everyone who I interviewed for this study, being on the stage was meaningful for at least two of my research participants, so it's reasonable to subsume this within our understanding of motivators for students to continually engage in science fairs.

Discussion

Findings from my research suggest the power of relevancy and autonomy – students consistently reported that they did research that was meaningful to them. This is one of the strongest connections to Expectancy-value theory (Eccles & Wigfield, 2002), as students conduct research, they are doing to be relevant to them and a worthy endeavor. More specifically, findings support the intrinsic value students enjoy in their engagement in doing scientific research and science fair, as well as the utility value of their activities (Eccles et al., 1983), as seen in the "it feels like you're making a difference" theme. Lillian, as an exemplar, noted the importance of her research – her experience of solving local and global problems using scientific research played a key role in her belief that her findings contributed to scientific literature. However, my findings cannot support connections between student engagement and their beliefs about competence in their work/expectations for success (Eccles & Wigfield, 2002). An interesting avenue for further research might be mixed methods approach that attempts to analyze EVT scales related to qualitative data such as what I collected for this study.

Furthermore, potentially connected to the development of science identity, my findings demonstrate that students more fully "see themselves among scientists" – consistent with other findings (e.g., Andersson et al., 2021). The theme "getting to be the expert" demonstrates a potential feedback loop between the student research presenter, and their audience, in a STEM recognition type format (Dou et al., 2019; Hall & Quinn, 2014). Interestingly, this could also be related to the idea that female scientists are under-acknowledged for their scientific works (Ross et al., 2023) in that student researchers in my study did get the opportunity to be acknowledge for what their research. Although we need to be cautious about claims related to the development of STEM identity, especially considering the contrasting findings of Dou and colleagues (2019) that science club and competition experiences, at least for grades K-4, did not predict STEM identity development.

As much as possible, students should not only be allowed to pursue research they find personally meaningful, but they should also feel well-supported by professionals in their endeavors. The outcomes could be transformative to students' futures as they begin to see themselves as among a community of scientists. The idea that features of a science fair, including that students get to engage in meaningful research and become the experts on their topic, are likely to support the development of science identity, which requires further investigation, as this has not been previously demonstrated by existing empirical research.

Finally, findings from my research support conclusions made by Nugent et al. (2015) that, while peer and family support is important for students in science learning opportunities, informal educators and teachers who serve as mentors have great potential to impact students in a positive way. Unfortunately, mentorship sometimes also results in unfair advantages to science fair participants, undermining the efforts of students who conducted research more independently or with less support (Schank, 2015). Sponsor teachers, professional scientists, and other mentors should thoughtfully support students in their productive struggles through their research processes without "giving them" the research process or outcomes. The students' perspectives here emphasized that the role of a mentor is to carefully scaffold our next generation of critical thinkers, problem-solvers, and the STEM workforce.

Limitations

This study has several important limitations including the narrow range of demographic characteristics for study participants, a single researcher as the instrument of investigation and self-report, the cross-sectional design, and limits to generalizability. These factors should be considered as we realize the importance of the findings.

Analysis of data revealed that students were sometimes recruited by sponsor teachers to engage in science fairs. If we consider equity issues, such as the opportunity gap, it is important to understand which students were recruited and why. As this study seeks to improve science research opportunities for all students (but most notably for females), there are implications regarding the demographics of students recruited to these opportunities. This warrants further investigation of questions related to sponsor teachers' decisions about who to recruit to participate in science fairs. For example, what criteria do sponsor teachers deem the most important when recruiting students to science fairs? A limitation of my study is that my data do not reveal the complexities underlying such decisions.

Even though this study collected student experiences with multiple science fairs, stretching across two or more years for most of them, this was not a longitudinal study. This design was not intended to directly show change as students participated in their first science fair compared to subsequent science fairs, especially as it is related to intrinsic or extrinsic motivators for their participation. This is an area to further investigate, as it is important to understand how students' needs for recognition and acknowledgement may change as students develop and as they engage in more science research experiences. We need to know, for instance, what mechanisms or processes are in play for students who initially participated for extrinsic award/recognition goals, but who may later participate for more intrinsic goals and/or the enjoyment of the research process. This is not a new question – Lewis et al. (1995), for example, suggested that student interest in science fairs may develop beyond the need for gratification from external rewards. The lack of a specific longitudinal aspect of the design also means that findings cannot specifically show growth in students' skills through their participation or examine whether there is a connection between that growth and the number of science projects completed.

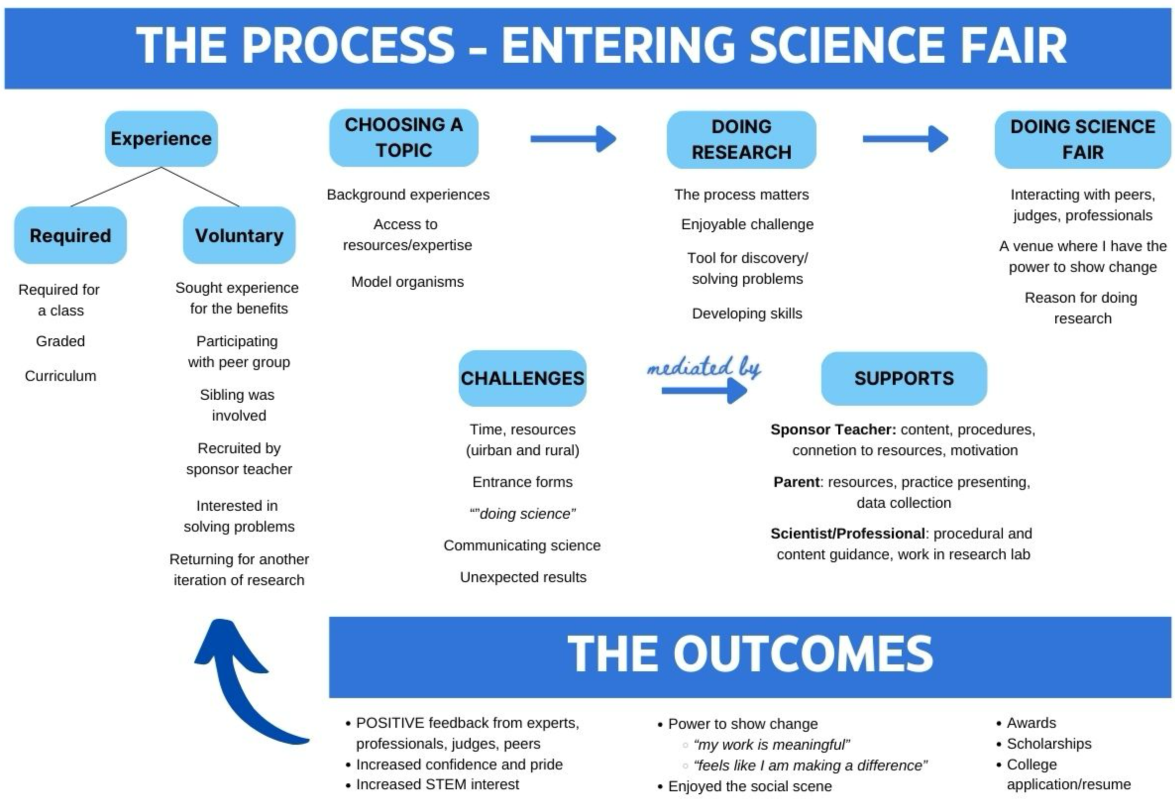
Qualitative research typically relies on the researcher as the instrument of data collection and analysis (Creswell & Poth, 2018). The research questions I asked contain assumptions about student processes to engage in science fairs. For example, my questions assumed that students encountered challenges as they engaged. Moreover, constructivist grounded theory acknowledges the interpretive nature of data collection and analysis due to the role of the researcher (Charmaz, 2014). As such, my findings must be contextualized considering this feature. Data analysis from a different researcher would likely vary from my own processes and findings. My findings also relied solely on self-report, not unlike quantitative surveys, though. This constructivist grounded theory methodology fully acknowledges reliance on the participant perspective, although I should note that this is typically viewed as a strength of this approach rather than a limitation.

Finally, I was able to develop a potential model that captures the process of students choosing to engage in science fairs, and contexts related to that. This model is grounded in the qualitative inquiry I used to investigate this phenomenon, but further inquiry will help to finalize various aspects of the theoretical model. Specifically, further qualitative or quantitative analysis could be used to determine students' perspectives of how their need for rewards changed over time while engaging in science fairs. Additionally, the model requires further testing across various contextualized settings.

Conclusion

A major strength of this constructivist grounded theory qualitative research design was its ability to yield a process-oriented theoretical model of secondary students' participation and motivational patterns in their choice to do a science fair, albeit a grounded model that requires further theoretical refinement (Pitts et al., 2023). As I previously noted, a holistic view of the participants' perspectives of their experience was missing from extant research on student motivation to do science fairs. Data from my study provides a rich, thick description of the processes for some students who chose to engage in science fairs and their subsequent experiences.

Figure 5
Theoretical Model: Why Female Secondary Students Choose to do Scientific Research for Science Fair



There are several key aspects of the theory that I developed through careful analysis of student interview data. First, while it is crucial that students get the opportunity to engage in science research and science fair activities, my findings indicate that the nature of the first experience, voluntary or involuntary, may not be as critical as other factors. For instance, students whose first experience was involuntary opted to continue doing science fair when the research they conducted was personally meaningful, they got to be the expert, and they felt like their research and the results they conveyed to an audience were making a difference.

Table 4

Participants 1st Experience with Science Fair

Participant	Required	Voluntary
Anaya	MS science fair school	
Belinda		7th grade - chose to do science club
Bethany	6th grade required	
Britney		7th grade sought out science club
Valaria	7th grade required	
Catherine	6th grade required	
Marcy		Jr. year - was interested in research
Tina	6th grade required	
Anna	8th grade required	
Moni	8th grade required	
Eileene		Recruited by HS teacher while in 7th grade
Jessup	8th grade required	
Allie		8th grade had option to do science research
Sondra		Wanted to do it since Jr. high, she saw others' success
Dalva	MS science program	
Mava		Voluntary but part of a science fair focused social environment - elementary
Senna	5th grade required for school	
Halsie		7th & 8th grade science club
Sereta	HS science requirement	
Lillian		7th grade science club

In addition, all study participants identified some sort of success with at least one of their projects. For some students, the extrinsic rewards were initially captivating and led to their continued participation. However, a few participants did note a lack of commercial success with one or more projects. Most examples of this included research that students identified as still being meaningful, and research in which they had a choice of the topic. Student choice and the meaningful work related to choosing to do science fair is likely a significant source of motivation above and beyond that of awards, scholarships, etc. Student choice appeared to be strongly related to their sense of doing meaningful work, i.e., students were choosing topics they found to be important, and this helped them create meaning in their projects.

Students identified slightly different outcomes from doing research compared to engaging in science fairs, although these two activities are intimately connected. Students viewed the research as a meaningful challenge – one that kept them engaged and drew them back to do more research. They identified the research aspect as a useful tool of discovery, leading them to investigations of personally meaningful topics. According to my participants, scientific research allowed them to help solve real-world local and global problems. In most instances, students did research specifically to take a project to their science fair. Students sought out the science fair experience for the positive outcomes they attributed to science fairs. For this reason, students knew they were going to be engaged in research. Their decision of *what* to investigate almost always came after the decision *to do* science fair (for students who participated voluntarily).

Increasingly, science standards like NGSS are calling for students to become proficient in the practices of scientists and engineers, i.e., scientific experimentation and inquiry learning. Findings from this study, along with other research, demonstrate students' self-reported gains in inquiry and experimentation skills. Science learning experiences, then, are supportive of the learning that takes place in many classrooms that seek to meet the requirements of NGSS. Furthermore, other research has noted the complementary nature of in-school science learning and science learning (Andersson et al., 2021), suggesting important links between the two types of learning. Students may benefit in both domains by engaging in the other. When educators can give students these opportunities, student growth in content and scientific process might be maximized.

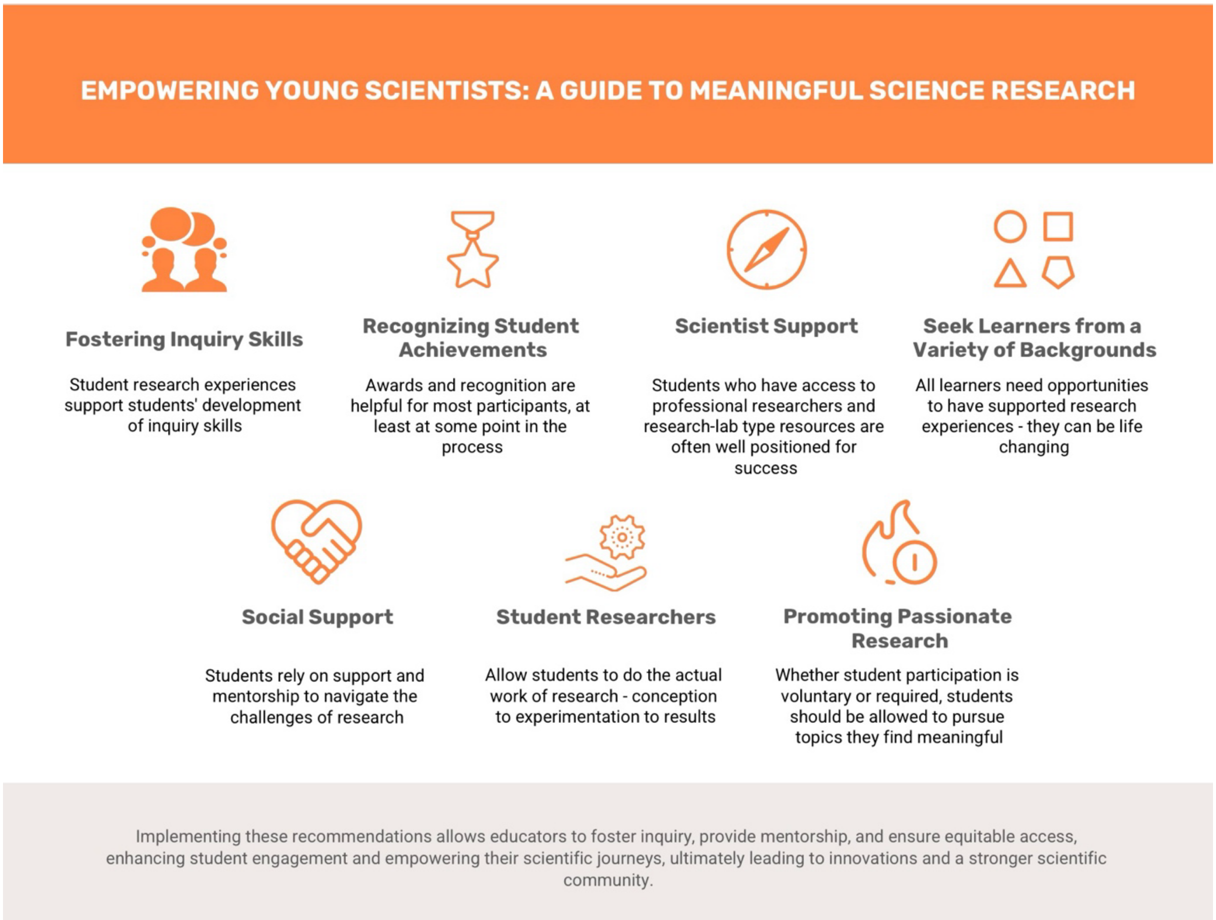
Bridging the Gap: Theory to Application

My findings provide important guidance, see Figure 5, for educators related to developing students' science identity and interest in STEM education and careers through their scientific research experiences. Primarily, these findings suggest a link between participation in science fairs and science identity. Student science identity might be influenced by extrinsic pathways such as awards, scholarships, etc., and intrinsic pathways presented through positive valuations of the research experience and the social interactions that occur during student engagement in science fairs. Furthermore, doorways to STEM careers may begin to open as students experience being the expert on their research topic and see themselves as members of a community of scientists, and thus, science as a career may become a more viable option. Science fair, these students told us, is a venue that can provide these opportunities. There are implications here for the importance of simply holding a science fair (do it!) and providing some type of award or acknowledgement of students' work.

Ultimately, the findings from this study are grounded in data from students who participated in science research through public school settings. Some of the participants might be considered "elite" students based on the courses they have taken and the research in which they engaged, while others would most certainly not. However, the nature of this research does not support causal claims about the "elite" status of the students being the reason for the research opportunities they experienced. Nor does it support the causal process suggested, where students become elite due to their science research opportunities. We can infer that either case is possible, and the truth likely lies somewhere in between. A possible process that was directly supported by the findings of this study was that the range of these research-rich, transformational experiences can take place in science research opportunities. As was the case for research participants, these experiences can occur through public middle and high schools, and in rural, urban, and suburban settings for diverse groups of students. This point should be empowering to parents, educators, and the science community as we look to not only bolster the STEM workforce but to provide opportunities through access to potentially life-changing experiences for our youth.

Recommendations to Educators, Administrators, and Other Stakeholders

Figure 5
Final research-based recommendations



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