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RESEARCH REPORT

Beyond the Leaky Pipeline: Developmental Pathways That Lead College Students to Join or Return to STEM Majors

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Abstract: *STEM education researchers often invoke the "Leaky Pipeline" metaphor (National Research Council, 1986) when explaining why so many students do not persist in STEM. This metaphor envisions the supply of potential workers as a pipeline. Students "drip out" (leave STEM) of the pipeline from preschool through college. However, this metaphor does not adequately reflect the fluidity and multi-directionality of students' decisions about their college majors. For example, some students join STEM after leaving another (non-STEM) major, and others add STEM as a second major. Increasing the number of students who join STEM could contribute substantially to addressing the STEM shortage. We used the term STEM joiners to refer to these students. We conducted a qualitative study of 22 college STEM joiners to explore the developmental trajectories and motivations of these STEM joiners. Data was collected through semi-structured clinical interviews with each individual and was analyzed by an iterative, grounded coding processes to derive themes and categories. We found that the decision to join STEM after declaring another major was often motivated by a desire to return to original interests in STEM. Early college STEM courses, supportive STEM environments, and mentoring experiences were critical in students' joining decisions. The results suggest ways in which STEM joining could be increased, which could lead to an increase in the number of STEM majors.*

Keywords: *STEM education, development, higher education*

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Introduction

The U.S. needs many Science, technology, engineering, and mathematics (STEM) experts for both current and future jobs (Langdon et al., 2011; Peri et al., 2014). However, about half of bachelor's degree candidates in STEM end up leaving STEM fields by either changing majors to non-STEM fields or leaving postsecondary education without earning a degree in the U.S. (Chen & Soldner, 2013). Thus, the U.S. does not produce enough STEM majors to meet current demand, and the problem is likely only to get worse.

The attrition in STEM majors is viewed as a primary cause of the deficit in the supply of STEM workers in the U.S. Consequently, most research on this topic has assessed postsecondary students' leaving STEM fields at different stages, as well as high school students' decisions to enter STEM fields (Alper, 1993; Anderson & Kim, 2006; Astin & Astin, 1992; Chen, 2015; Green & Sanderson, 2018; Hall et al., 2011; Perez et al., 2014; Seymour, 2000; Wang, 2013; Xu, 2017).

The Leaky Pipeline Metaphor

In characterizing the causes of the STEM shortage, many researchers invoke the Leaky Pipeline Metaphor (National Research Council, 1986; See Figure 1 for an example). The entry pool of potential STEM workers is quite large at the elementary and middle school level, but many students lose interest in subsequent grades or stages and focus on other, non-STEM subjects. Thus, the number of students interested in STEM shrinks at all stages of education; the supply pipeline that leads to qualified STEM workers is therefore very leaky.

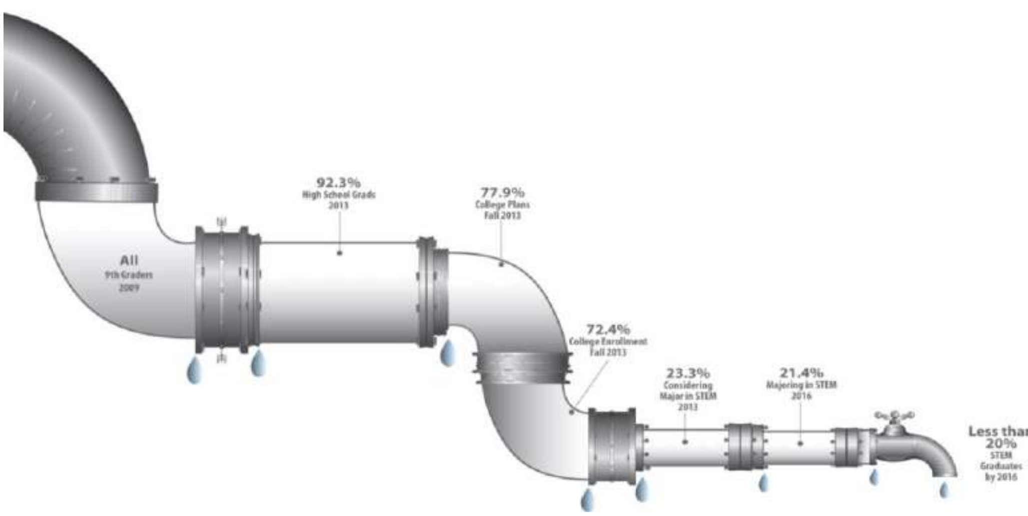

Figure 1. Leaky STEM Pipeline. Potential STEM workers drip out at every major transition point. Drawing by Lynn Pearson; copyright belongs to the authors. The data source is NCES HSLS:09 (National Center for Education Statistics, High School Longitudinal Study of 2009).

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The pervasive leaky pipeline metaphor has greatly influenced how researchers and educators interpret and attempt to rectify the shortage of U.S. STEM workers. The Leaky Pipeline has, in fact, become a "metaphor we live by" (Lakoff and Johnson, 2008), structuring how we conceive of the STEM shortage and of possible solutions to it. For example, there is great emphasis on "patching" the pipeline—finding ways to keep people (particularly women and minorities) interested in STEM so they do not "leak" (e.g., Gasser & Shaffer, 2014; Minefee et al., 2018). Likewise, efforts to understand why women and minorities are underrepresented also focus either on leaks or lack of adequate supply from the beginning (Anderson & Kim, 2006).

Limitations and critiques of the leaky pipeline

The leaky pipeline metaphor has helped to frame and highlight the STEM shortage, but it has some important limitations. First, it implies that STEM fields are particularly leaky in comparison to other fields, but this may be an exaggeration. At least at the college level, STEM fields are only slightly more "leaky" than other fields (Chen & Soldner, 2013). For example, Leu (2017) reported that 35% of the students who originally declared STEM majors switched their majors during college, and that 29% of students who declared non-STEM majors also switched majors. Leu's (2017) report was based on the Beginning Postsecondary Students Longitudinal Study (BPS: 12/14), a nationally representative study of about 25,000 students. "Leaking" (i.e., leaving a college major) is thus a common event, regardless of whether a student is a STEM or non-STEM major. Thus, it seems unlikely that differential levels of leaking are the primary cause of the STEM shortage.

The second important limitation of the leaky pipeline metaphor is "its emphasis on a neatly linear progression through a fixed set of benchmarks" and that "it diminishes variation in the motivation for pursuing STEM courses and the range of experiences they may offer" (Cannady et al., 2014, p. 448). The leaky pipeline metaphor is unidirectional; it focuses only on students who leave STEM and does not consider the possibility of students entering a STEM field after declaring other, non-STEM majors. However, unless they leave college or university entirely, students who leave one major usually declare another major. Thus, across the university, it is common for students to not only leave one major but also to join another (e.g., Lykkegaard & Ulriksen, 2019). Put simply, the leaky pipeline metaphor does not help us to frame the fluidity of students' major selections.

Beyond the Leaky Pipeline Metaphor: Situating the Problem in a Developmental Context

The challenges to the leaky pipeline metaphor have led some scholars to consider alternatives and to view the STEM shortage issue in a broader, developmental context. Particularly in early adulthood, development often involves an iterative series of choices and the experience of their consequences, sometimes in the context and sometimes on self-identities. For

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example, work in developmental psychology stresses the dynamic and at times unstable nature of students' emerging identities, as it is reflected in their college majors (Arnett, 2000; Arnett, 2004). For young adults who attend college or university, the selection of a major (or majors) is often very challenging, and they may change their minds frequently when they make important decisions. (Arnett, 2000; Arnett, 2004; Goldscheider & Goldscheider, 1999). The process of both selecting and completing a college major is thus not only about what one will study; it is also about committing to an identity (Erikson, 1968; Phinney & Alipuria, 1990). For many college students, the selection of a college major is the first step in choosing an occupation, and thus this decision is particularly important for the identity development process (e.g., Erikson, 1968; Grotevant et al., 1986; Lent, et al., 1994; Seginer & Noyman, 2005; Skorikov & Vondracek, 1998). Therefore, students' educational choices become central to their future employment and the formation of a career identity (Arnett, 2004; Creed & Hughes, 2013; Lehmann & Konstam, 2011).

The challenges of choosing a major may be particularly strong in the U.S. because students can easily change majors. In contrast to many other countries that have more restricted policies on students' major declaration (e.g., China, South Korea, Switzerland), students at many four-year American colleges or universities can take up to two years before declaring a major. Moreover, they often still can also easily change their minds after declaring one major and switch to or add another. In combination, these characteristics of the American higher education system mean that students have time to think about and try out different majors. Thus, many American students change majors at least once, and sometimes multiple times (e.g., Arnett, 2004; Arnett, 2016; Cheah & Nelson, 2004; Creed & Hughes, 2013; Lehmann & Konstam, 2011; Nelson & Padilla-Walker, 2013; Tanner, 2006), depending on how flexible the universities' major declaration policies are.

Although STEM and non-STEM majors both change majors (or add a second major), most research focuses only on those who leave STEM fields to join non-STEM fields. We know much less about movement in the opposite direction: entering a STEM major after beginning in one of the non-STEM fields. In fact, there is possibly an often overlooked group of STEM joiners—individuals who come to STEM after leaving another major, or who add STEM as a second major after initially declaring a non-STEM major, or who declare a STEM after remaining decided during the first or two college years. For example, in an analysis of the more recent Beginning Postsecondary Students Longitudinal Study (BPS: 04/09) data set, (Wine et al., 2011). Miller (2018) found that 23% STEM graduates entered STEM from the "undecided" category and another 18% of STEM graduates entered STEM from non-STEM majors. Thus, up to 41% of STEM degree holders in the BPS: 04/09 dataset were not initially majoring in STEM when they first started college.

The existence and frequency of joining STEM from either another major or from undecided raises a new and potentially fruitful way to address the STEM shortage: increasing the number of students who join STEM. Increasing the rate of STEM joining might be as or more effective than increasing persistence (aka preventing leaks in the pipeline). Thus far, most work has focused on preventing pipeline leaks, but our analysis indicates that broadening the conceptualization of possible solutions to include STEM joining may also help to redress the problem. In fact, increasing STEM joining rate by just 5% might potentially produce 63,000 more STEM graduates per year (Miller, 2018).

In summary, to understand the STEM shortage, and to begin to redress it, we should extent our conceptualization beyond the leaky pipeline metaphor. STEM joining and STEM leaving are both part of a larger developmental process. The selection and re-selection of a college major is part of a dynamic, developmental system. Therefore, we should consider movement in both directions, both out of STEM and into STEM, because students often change majors as they develop their personal and professional identities.

Current Research

Thus far, most studies of STEM joining have been based on large-scale surveys (e.g., Cannady et al., 2014; Lykkegaard & Ulriksen, 2019; Mervis, 2014; Miller, 2018). These studies provide information about the existence of STEM joining and its possible importance. However, prior survey studies may not provide the kind of detailed information that is needed for faculty, administrators, and peer mentors to find ways to increase the number of STEM joiners. Although many studies have examined STEM "leaking", there has been substantially less research on STEM joining. We suggest that we need research on both STEM "leaking" and STEM joining to address the STEM shortage effectively. Here we sought to complement and extend the few studies of STEM joining that have been conducted (Cannady et al., 2014; Lykkegaard & Ulriksen, 2019; Mervis, 2014; Miller, 2018). We augment prior large-scale, correlational studies of STEM joining with a detailed, qualitative study of the characteristics of STEM joiners. A more focused and detailed analysis of the characteristics and pathways of STEM joiners is needed to understand their motivations for joining STEM and the developmental pathways that led them there. This approach is complementary to the surveys; it will give us a broader (and more accurate) perspective on the process of becoming a STEM major and will also highlight new ways to increase the number of STEM majors and graduates.

The primary goals of this research therefore are to understand the motivation of STEM joiners, to sketch out the developmental pathways of STEM joiners, and to analyze the narratives that students construct about these developmental changes. Specifically, our research questions include:

a) When did the students join STEM?
b) What were they studying before they joined STEM?
c) Why did they join STEM?
d) What were the developmental pathways that led them there?

We argue that the decisions to join STEM must be viewed in a broader context that traces back to years before college to better understand students' changes and development. We addressed the motivation of STEM joining by not only focusing on some critical events that affected STEM joiners' decisions to join STEM fields, but also paying attention to critical people involved in the critical events. Considering these events and influence of critical people could illuminate some interesting narratives and help us mapping out the developmental trajectories.

Method

Approach

To achieve our goals of uncovering the characteristics of STEM joiners and understanding their motivations and pathways, we took a qualitative approach and conducted in-depth interviews on a group of students to learn about their personal stories. Qualitative scientific research methods can provide thick descriptions (Geertz, 1977) of people and contexts, inform the development of theories (Sofaer, 1999). Qualitative methods can be construed as a complement to quantitative methods; the qualitative methods provide very detailed information about a relatively small number of participants, whereas quantitative studies typically provide less detailed information about a much larger number of participants.

Participants

Operationalizing STEM joining

We defined STEM joiners as individuals who did not start college as a STEM major but added a STEM major sometime in college. This definition could include students who switched from a non-STEM major to a STEM major as well as students who added a second, STEM major while keeping their original non-STEM major. Our definition of "STEM majors" follows the National Center for Education Statistics' classification of STEM fields, which mathematics, physical sciences, biological/life sciences, computer and information sciences, engineering and engineering technologies, and science technologies, but excluded social sciences and health/nursing (Chen & Soldner, 2013).

To recruit STEM joiners, we sent emails to faculty who, were teaching an introductory STEM class when we collected data in one of the following topics: Chemistry, Physics, Biology, Computer Science, Math, and Engineering. After obtaining IRB approval, we emailed the instructors, asking them to forward our recruitment information to the students in their classes.

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We also contacted STEM departmental staff through departmental online directories, asking them to send project information to their undergraduate mailing list. We invited students from several private and public universities in the Midwest and in the South, as well as liberal arts colleges in the Midwest to participate.

We recruited a total of 22 undergraduate students (11 males and 11 females) ranging from second year to fourth year who met the criteria of STEM joiner as described above. 17 of the STEM joiners attended an elite private university in the Midwest, 4 attended liberal arts colleges in the Midwest, and 1 attended a regional state university in the South. The liberal arts colleges have the most flexible major declaration policies that students could remain undeclared till the end of their second year. The rest of the institutions also have relatively flexible major declaration policies that students may have up until their third year to finally settle down on their major(s). Participation was voluntary, and we compensated students with either $10 cash or a $10 Amazon gift card.

Materials

We developed a semi-structured interview protocol (see Appendix A for details) to assess several themes relating to a student's choice of major, career aspirations, and identity formation. The interview protocol was informed by prior research on STEM "leaking" (e.g., Seymour, 2000) and was developed to maintain openness that could potentially lead to some interesting conversations. The semi-structured approach gave us flexibility to invite respondents to expand on specific comments and allowed us to ask tailored questions that helped to uncover students' narratives regarding their decisions to join STEM.

The interview had four sections; examples of questions are given in Appendix A. The four sections were designed to answer the research questions posed above: a) When did the students join STEM? b) What were they studying before they joined STEM? c) Why did they join STEM? and d) What were the developmental pathways that led them there? The first section was demographic information; we asked each student his or her major, year in school, and when he or she joined STEM. This section allowed us to tap into our first two research questions around students' time of joining and their previous majors. The second section was pre-college experiences, which included questions about students' memories of their career aspirations when they were younger, and their impressions of STEM when they were in high school. This section was designed to discuss prior experiences of the students and uncover traces on why these students did not start with a STEM major in college. The third section, decision process, asked about college major and career identity formation. We asked students about their decision to join STEM and whether the respondents had taken any STEM courses before they joined STEM. If they had, we asked them to elaborate on their STEM course experiences. We also asked them to think about whether a specific person, such as professor, teaching assistant, or parent, played an important role in the decision process. This section was the major focus of our interview protocol, and we sought to awaken students' memories by asking them to reflect on some critical events or critical people. The final section, comparing STEM and Non-STEM courses, asked students to think about the difficulty of studying STEM subjects versus studying non-STEM subjects. This section allowed us to compare students' impressions on both STEM and non-STEM as well as to potentially understand why they picked one over another.

Although we prepared some questions prior to conducting our interviews, the protocol was not rigid; we continuously refined and augmented the questions according to participants' responses. We attempted to maintain a natural flow to the conversations rather than rigidly following the interview structure. We always pursued new issues that participants mentioned that were pertinent to their joining. For example, one participant mentioned that his parents were both immigrants with strong scientific backgrounds. We treated this as an indicator relevant to our conversation and elicited more information on this topic to find out what specific influence the parents had on his decision to study a certain major. This iterative strategy allowed us to cover as many possible factors that affected students' decisions to join STEM as possible, and therefore led us to a more comprehensive understanding of STEM joiners.

Procedure

Participants first provided informed consent. Some interviews were conducted in-person where possible, while some were conducted remotely via Skype. Interviews were conducted on a one-on-one basis, and each interview lasted about an hour. We took notes during the conversations and recorded the audio using a high-quality portable recorder. All the interviews were later transcribed verbatim, with the assistance of version 2.2.3 of the transcription software InqScribe (2015) or through a professional transcription service.

Analysis

The first author conducted an iterative inductive coding process, and both authors were involved in the discussion of organizing and summarizing elements from the coding into richer developmental pathways.

Inductive coding

We began with a bottom-up, grounded, inductive coding (e.g., Bryman & Burgess, 2002; Miles, et al., 2013; Strauss & Corbin, 1997). Inductive coding was the best way of realizing our goal as it allowed for open and unrestricted analysis of our data. This inductive coding had two phases. The first was an in vivo coding (Miles et. al., 2013), in which we read through the transcripts several times and focused participants' own words to begin to identify themes and categories. Phrases that are used repeatedly by participants are often good leads, and this method prioritizes and honors the participants' voice. For example, the code "not a STEM person in high

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school" came directly from our participants' words; we noticed that several students said they didn't think they were talented in STEM in high school. This strategy of using the respondents' own words as codes sheds light on what the individual respondent thought were important aspect of his or her own journey of joining STEM. Moreover, in vivo coding allowed for a close look at students' change in selves and affect at the moment. Also, because we only asked probing questions and most of the points were brought up by the interviewee him or herself, in vivo coding could potentially capture the most striking points related to our inquiry without being constrained by our prior knowledge.

Our second inductive method was a descriptive coding (Miles et. al., 2013) strategy, in which we began to summarize students' responses and capture the decision factors of joining STEM. The purpose of the descriptive coding was to move beyond very specific moments and an exclusive focus on interviewee's own words to a somewhat more general (and less granular) description. For example, our in vivo coding revealed many responses that referred to mentoring in some way. We therefore developed codes of "mentoring from professors" and "mentoring from TA/graduate students" to capture those responses. Likewise, we developed a code of "career consideration" to capture responses in which students talked about their future career planning when deciding whether to join STEM. These descriptive codes eventually could provide an inventory of topics for further indexing and organizing. Taken together, the two inductive and convergent coding approaches allowed us to address the factors that influenced STEM joining at both macro and micro levels, while simultaneously facilitating the development of a succinct, accessible coding system. Appendix B is the inductive coding system.

The processes of defining and identifying themes were iterative (Miles et. al., 2013). We continued refining our coding system as new themes emerged, until no more new themes emerged, which suggested that we had identified main themes. After the coding system was developed, we reviewed and discussed all the transcripts again to ensure that all the decision factors of STEM joining were coded.

Describing students' trajectories

The codings described thus far helped us to understand the key events or experiences that students mentioned in their interviews. Our next step was to organize these key events and experiences into coherent developmental trajectories. Students' descriptions of these events often included not only the event itself (e.g., "I took a [computer science course] in the fall"), but also a description of associated feelings and beliefs (e.g., "I had a really good time with it. It felt very comfortable to join the major after that.") The stories that students shared integrated events and belief changes across several years, usually from the middle or high school through the middle years of college. For example, the code "dreams and goals related to STEM" would fall under the category of "initial interest in STEM", while the codes "supportive STEM environment" and

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"mentoring from professors" would both fall under the category of "join (or return to) STEM". These trajectories were derived from our interpretation and organization of the codes shown in Appendix B.

In summary, our analysis relied both on coding specific elements of the individual interviews and on summarizing these elements into richer developmental pathways. This multi-step inductive approach provided us a thorough analysis of STEM joiners' memories of and interpretation of their developmental pathways.

Results

Our analyses of the interviews addressed four general questions: a) When did the students join STEM? b) What were they studying before they joined STEM? c) Why did they join STEM? and d) What were the developmental pathways that led them there? The last two question are the most intensive and addresses the central questions regarding the motivation for and pathways to STEM joining.

When Did They Join STEM?

To better understand joining STEM in a developmental context, it is important s to find out when students joined STEM. Our interviews revealed that most students joined STEM during their first or second year in college. All but 3 of the 22 respondents joined STEM before they started their third year. This is not a surprise because universities and colleges often require students to declare before the end of the second year and joining STEM after the sophomore year would be much more difficult due to the large number of required prerequisite courses.

Prior Majors or Course of Study Before Joining STEM

We identified two distinct types of STEM joiners based on the participants' responses to our interview question of their previous and current majors. The first group is students who left their original non-STEM major or intended non-STEM major and switched into STEM. We will refer to this group as STEM Switchers. Seventeen out of the twenty-two participants belong to this group. The second group is students who added a second STEM major while still keeping their original non-STEM major. We will refer to them as STEM Adders. Five of the participants belong to this group.

Motivation for STEM Joining: Why Did They Join?

Our first phase of inductive coding analysis revealed that the three most common factors that affected students' decision to join STEM were STEM course preparation, experiencing supportive STEM environments, and individual mentoring from professors or graduate teaching assistants in STEM. We first describe each factor, using supporting evidence from our interview transcripts. We then present the results of integrating these factors into the students' pathways of joining (or returning to) STEM based on our second analysis approach mentioned above and further interpret them

STEM course preparation

STEM course preparation refers to STEM classes taken before college or during college as a non-STEM major. All the respondents had taken several STEM classes before they joined STEM. This result is consistent with previous large survey analysis that STEM course preparation is positively correlated with STEM joining (Miller, 2018). Although all the respondents were not enrolled in a STEM major at the beginning of their college careers, they started taking STEM courses early in college, often before they joined STEM. These courses often were taken to fulfill college or university distribution requirements. Students' experiences in these courses often turned out to be critically important in the decision to join STEM. Respondents often reported enjoying the STEM courses and earning good grades (often to their surprise). The initial success prompted further interest in STEM and the taking of additional STEM courses. Thus, many students continued to take STEM courses even if those were not required for their original majors. Taking STEM courses early on in college could not only help potential STEM joiners develop interest in STEM subjects but also help them satisfy major requirements in STEM disciplines so that they can graduate on time even if they switch majors. This is especially beneficial and important because STEM majors often require many credits for a degree. Thus, early STEM course experiences could potentially increase the chance of becoming STEM joiners.

Next, we looked further into students' STEM course experiences, to find out what was special about these experiences that motivated students to join STEM. Two important aspects became evident: (a) supportive STEM course environments, and (b) individual mentoring from a faculty member or more advanced student.

Experiencing supportive STEM environments

Students often mentioned the importance of positive and supportive STEM course environments as one of their motivators to join STEM. For example, some respondents noted that in an introductory level, very large computer science course, a professor tried very hard to remember students' names and allowed students to call her on a first-name basis. Students reported that this level of familiarity was rare in STEM classes as professors in most STEM classes tend to be more distant from students. The professor's supportive approach made students who were new to STEM feel more comfortable to try out STEM courses. It also increased the likelihood that students would continue to take STEM courses, and therefore increased the possibility that students would later join STEM. The faculty member also stressed that the course was appropriate for students of all levels of ability and prior experience. Students reported that this

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professor occasionally said in class, "close your eyes… raise your hand if you think we're going too fast… raise your hand if you think we're going too slow… raise your hand if you think we're going just right." Then, the professor would adjust the pace of instruction accordingly. The students often reported doing well in this and similar STEM courses, which possibly helped to negate the (often false) belief that they were not sufficiently talented or prepared to do well in STEM.

Individual mentoring from STEM professors, TAs, or peers

Many students also pointed out that there were specific faculty members or peers who provided substantial support in the form of mentoring in their STEM joining. By mentoring, we mean the naturally occurring, supportive relationships that students have with older and more experienced individuals. Mentoring often occurs outside of class, such as during office hours, at a club meeting, etc.

One respondent talked about having several conversations with the same professor:

> He (the professor) called me... he was concerned I didn't know what I was doing, so we met and then... he was worried that it was too much for me... he was surprised and pleased with how much work I was able to get done. So, junior year, actually by later sophomore year, I went through a phase of whether I should do a biology or chemistry major, and he asked me to do a chemistry major (a male junior English to Chemistry switcher).

As the students pointed out, having several conversations outside the classroom is not very common in STEM fields, but this professor volunteered his time to talk to students and created a welcoming and friendly environment. The professor did not blindly or selfishly push the student towards chemistry; instead, he showed concern for the students and paid close attention to their progress and development. The professor asked the student to switch to a chemistry major only when the student was ready, and his words directly affected this student's decision.

TAs and other graduate students also often played key roles in helping to assuage students' concerns and lack of confidence. Participants benefited substantially from graduate students sharing their own narratives about becoming STEM majors. Consider the following quote from a student who switched from sociology to chemistry:

> many graduate students offering their perspective... talking with me about what to do in life and also… I realized that some of them actually did have quite a bit of interest in the social sciences… and were able to talk about some of the issues and politics in society pretty well, and I was surprised by that. And I realized that… you are able to still maintain a strong background in the social

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> sciences with the science major... so that's what I realized (a male senior Sociology to Chemistry switcher).

The student was afraid that a person with social science background would not succeed in STEM. TAs from the summer course helped him to understand that is not true, and this gave him the courage and confidence to study chemistry.

Many participants mentioned mentoring experiences either with faculty members or with TAs/graduate students, pointing out that these experiences were often critically important in their decision to join STEM. The interaction often went beyond attending classes and became more personal and meaningful. These themes emerged as students constructed their STEM identities and pathways into STEM by telling us their narratives.

Career considerations

Many students attributed their decision to join STEM to career concerns in the other major; the students were concerned that they might not be able to find a job in their original major, and that either joining or adding the STEM major would help in this regard. This factor was brought up mostly by double-major students who added a second STEM major to their original non-STEM majors. Computer Science was the most common second major. Computer Science is a flexible major that can be added to almost any other major (Margolis & Fisher, 2003). Students cited many different reasons for better career outcomes with their added computer science major. For example, one student thought her two majors – communication studies and computer science – supported her goal of finding a career in human-computer interaction. She realized that adding a computer science major would give her more opportunities and reduce the risks associated with finding a job in the film industry. She observed,

> I bookmark articles all the time on my computer, and I just screenshot everything about, like, how there's someone right now going to uhh... the Silicon Valley to try to get people to go into defenses instead of going into, you know, these other industries within computer science. And I'm just looking at these, thinking I would love to do this (a female junior Communication Studies and Computer Science STEM adder).

Likewise, another student chose to add a computer science major because it is more related to her original journalism major. She said, "there is more overlap" and she wanted to use computers to tell stories.

Therefore, these students joined STEM not only because they had interest in it, but also because they considered STEM to be something useful for their career path, even if STEM was not their only major. Earning a STEM degree would equip them with knowledge and skills that they need for their desired career.

Synthesis of Themes and Categories

Having identified the key influencers of students' STEM joining decision, we then contextualized these key factors into a developmental trajectory that describes routes to becoming a STEM joiner. Our coding and analysis revealed that students' trajectory of becoming STEM joiners often consisted of three core stages or processes (see Figure 2): a) initial interest in STEM, usually in high school or even before b) leaving STEM fields before or when coming to college; and c) joining (or returning to) STEM. This trajectory describes most but not all respondents' journeys, and it is especially relevant for the STEM Switchers. Figure 2 provides a summary of both students' narratives and the elements that emerged in the inductive coding.

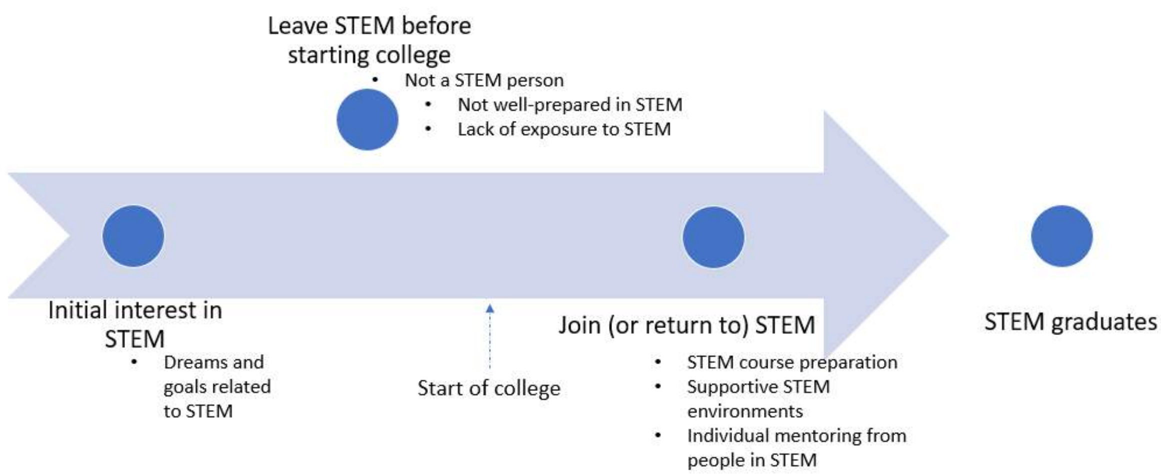

Figure 2. A possible pathway of STEM joiners from pre-college to college.

Initial interest in STEM

As Figure 2 shows, the trajectory usually began with students' dreams and goals related to STEM before they came to college. Many students reported that they had been interested in STEM topics in high school or earlier and had seriously considered declaring STEM majors in college. They had also completed the necessary high school courses to allow them to begin a STEM major in college, and many reported taking several Advanced Placement courses in Chemistry, Physics, Biology, or other STEM topics.

Deciding initial not to pursue STEM

Once the students began taking college courses, their initial plans or desires to major in STEM began to fade. Many of the respondents expressed anxiety about whether they would succeed in a STEM major, with many attributing the problem to a lack of adequate high school preparation. This (often false) belief may have arisen students comparing themselves to other students in the prestigious universities or colleges. Thus, they concluded that they were not a "STEM person" and decided not to pursue a non-STEM major. (Note that this could also happen in college).

For example, one participant who switched to chemistry from sociology said, *"my dream was to become a doctor, but then my high school was not really strong in the sciences... it was actually pretty strong in the social studies."* He dreamed of have a STEM-related career while he was young, but he thought his high school didn't prepare him well enough for a STEM major. That hindered him from entering a STEM major when he came to college.

Another student who later switched into math expressed a similar idea. *"So I've always wanted to do something with science and math. I just, there were so many things in my way… So yeah I've always had that in the back on my mind. I just never had the courage, you know, to do it. And I never thought I was good enough."* The assumption that they lack the necessary confidence or preparations seems to be a key factor in leading students to leave the STEM pipeline.

Joining (or returning to) STEM

Nevertheless, the students still took STEM classes, perhaps simply because these classes were often required as curriculum distribution requirements. Thus, even though they thought they would no longer major in a STEM field, they still ended up taking some STEM courses. These courses proved to be very important in their decision to change (or add to) their current major and return to their original interest in STEM. The courses supported the return to STEM in at least two ways. First, they helped the students to see that they could succeed, despite their beliefs that they were underprepared or underqualified for STEM majors. Second, in the context of taking these STEM courses, the students often experienced the supportive STEM environment with help from mentors, either professors or graduate students. The mentoring experiences helped to reinforce the nascent belief that the student could succeed in a STEM major, and also provided a forum for asking questions, addressing doubts and concerns, and learning about other students who had followed a similar trajectory. Consequently, they decided to "return" to STEM and pursue their original interest.

STEM joining is thus often part of a larger narrative in which the act of joining STEM is actually viewed as a return to one's true interest. Students often reported being happy about their decision of coming back to STEM; their interview responses often conveyed a sense of found purpose or meaning. The students saw joining STEM as much more than being forced to study popular majors that they did not like; it was actually a decision that led them back to something they had enjoyed (usually in high school) and had truly wanted to pursue. The overall trajectory traced back to students' experiences before college and sketched out their journey in college.

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Discussion

The STEM shortage is one of the most severe challenges in American's workforce. STEM joining is a potentially critical but often overlooked component of the overall supply of STEM majors; STEM joiners can help to replenish some of the "leaks" in the STEM pipeline. Efforts to produce more STEM workers should go beyond just preventing students from leaving STEM and should be expanded to include motivating students to join STEM. This paper has considered the motivations and developmental trajectories that lead college students to join STEM.

The results reveal that students' decisions to join STEM involves far more than the decision to switch or add a STEM major. The students did not suddenly have an epiphany that led them to switch to or otherwise join the major. Instead, the decision to join STEM must be viewed in a dynamic, developmental context in which various experiences have changed and reshaped students' choices and beliefs.

Finding that students may join STEM from another major is not new, but highlighting the narratives that students construct around joining STEM is a novel contribution of this paper. Identifying these narratives helps to expand conceptions of the causes and remedies for the STEM shortage. "Leaking" from the pipeline is indeed a serious concern, and most of the students in our sample saw themselves as "leakers" from the pipeline; many had intended to major in STEM and had taken the necessary high school courses, but they chose another non-STEM major in college. However, our results also illustrate a fundamental limitation of the Leaky Pipeline metaphor: the "leaking" was not necessarily the end of the story---some students did return to STEM. The leaky pipeline metaphor has perhaps led us to ignore the more complex but much more interesting developmental pathways that are associated with the decisions to enter, leave, persist, or re-enter STEM fields. Such rich details were only available to us through the in-depth qualitative interviews and the grounded approach to our analysis.

Moreover, our findings revealed that STEM joiners often had three common characteristics: early STEM course preparation, supportive STEM environments, and receiving individual mentoring. These characteristics have received some coverage in prior research on STEM pathways (e.g., AAUW, 2010; Ong et al., 2011; Stout et. al, 2011; Wang & Degol, 2013), but our qualitative approached allowed us to have more of a contextual narrative for these characteristics.

It is well documented that early STEM course-taking and the associated grades can often predict students' original declaration of STEM majors or retention and persistence in STEM (e.g., Bottia, et al., 2015; Riegle-Crumb, et al., 2012; Tyson, et al., 2007; Wang, 2013). However, these studies only consider major selection in STEM as a unidirectional process. On this view, STEM students either persist or they leave the majors. Our research suggests early STEM course-taking also influences whether students who leave STEM ultimately return, or whether non-STEM majors add a second, STEM major. Thus, the decision to add, leave, or return to a STEM major is part of a larger and fluid developmental process.

Similarly, our work may support taking a different perspective on the influences of campus culture, especially for women and underrepresented minorities who often experience stereotype threats in STEM (e.g., Espinosa, 2009; Johnson, 2012; Ramsey et al., 2013; Szelényi et al., 2013). Almost always, these studies focus on whether the campus culture promotes STEM persistence; these studies usually do not consider majoring in STEM as a dynamic and evolving developmental process. Our research, on the other hand, expands the findings of the previous research and provides evidence for the possibility of re-entering STEM. It is important to examine whether increasing STEM joining could help to increase the number of women and minorities who major in STEM.

Previous research has also shed light on why factors such as individual mentoring from professors or peer advisors strongly influenced students 'development and major selections. Individual mentoring and providing role models help to confront the stereotype that pursuing a STEM major is difficult and prone to failure. Prior research has shown that such mentoring can contribute substantially to persistence, and here we showed that mentoring could play a critical role in STEM joining. Once a student has "leaked" from STEM, a supportive mentor may be the key factor in helping the student to see the possibility of returning to STEM. The success of the role model becomes a positive representation of the original underrepresented population, and students may then seek to emulate this positive role model (Eschenbach, 2015). At the same time, peer advisors play an important role because the experiences they shared demonstrate the difficulties are shared.

Limitations

There are some limitations of the study we need to recognize. Firstly, our sample size is not large, but our focus was on a qualitative, detailed analysis of individual participants. Our results suggest potential approaches and questions for future research. For example, the "returning" pathways might be further investigated in future quantitative research. Secondly, our results do not reveal much about how experiences and narratives may differ for different genders or races. We did not focus on gender or racial differences in our study, as our goal was to explore the under looked group of STEM joiners and illuminate some of their experiences and trajectories. In the future, researchers could ask specifically whether and how people with different gender and racial backgrounds differ in their experience of joining of STEM. Thirdly, our research only examined STEM joiners and therefore we could not identify whether these experiences were unique to STEM joiners or could also be found on STEM leavers. Future research can compare joiners and other groups (e.g., STEM leaver or STEM stayers). Finally, more

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information could be gained if we follow students and interview them multiple times, including after they graduated.

Implications

There is more to the STEM supply problem than leaks; a lack of replenishment through STEM joining is also a serious problem. Therefore, the solution to the STEM shortage cannot be only to fix the leaks. Instead, to fully understand, and perhaps to redress the STEM shortage, we need to consider what happens after the "leak". A relatively small but potentially important group of students do return to STEM after they have "leaked". Facilitating STEM joining or returning could substantially increase the number of successful STEM graduates in the U.S. Encouraging students to join STEM after starting a non-STEM major might be a very effective and efficient way to address, in part, the STEM shortage. We acknowledge that our results were based on a qualitative research with a sample of 22 participants, and more research is definitely needed, but we also believe that these results could already enable us to make some suggestions on how to potentially encourage STEM joining.

Addressing false beliefs about preparation for STEM

In this regard, the results do shed light on some possible ways to increase the number of STEM joiners and to make those considering STEM majors more comfortable and confident in that decision. For example, one important remedy would be to address students' beliefs that they were not adequately talented or prepared to study STEM in college. We have labeled this a false belief because it is empirically not true; almost all of participants had more than adequate preparation to pursue a STEM major, as defined by the relevant departments. For example, almost all of our respondents had taken four years of math and science in high school. Moreover, many had taken and done well in several STEM Advanced Placement classes. Nevertheless, they consistently reported feeling underprepared to be a college STEM major.

Students' beliefs about inadequate preparation or qualifications for majoring in STEM may be an example of pluralistic ignorance, in which many people in a group hold the same false belief but are not aware of others' beliefs (e.g., Miller & McFarland, 1991). If so, some of the same techniques that have been shown to be effective for redressing pluralistic ignorance may work in this situation as well. For example, posters, brochures, or social media campaigns aimed at increasing or retaining STEM majors might point out that many people falsely believe they are not qualified to major in STEM, but that this belief is incorrect. The technique of correcting pluralistic ignorance to address a social problem has worked in other contexts, such as reducing alcohol use among college students (Schroeder & Prentice, 2006). Telling students that many of their peers did not drink helped to reduce the pluralistic assumption that most college students drink heavily, which in turn made sobriety feel more normal. Likewise, explicitly telling students that many feel unprepared to study STEM, but that they are adequately prepared, might help to address this consistently held false belief.

Mentoring

Faculty need to be made aware of the possibility of STEM joining, and the important role that they may play in instigating the move back to STEM. University mentors can now be explicitly aware of the "returning to STEM" trajectory, and they may help students realize their potential and fulfill their goals. First-year college advisors could be made aware that students' claims of "inadequate preparation" might be an indirect indication of a loss of confidence. This would allow the advisors to help initiate the mentoring that proved so critical in the decision to join STEM.

Curriculum considerations

Our results suggest that all the STEM joiners started taking STEM courses even before they officially "joined" STEM, and many noted that their success and enjoyment of these courses contributed to their decision to return to their original, intended focus on STEM. This finding suggests that both the timing and quality of early STEM courses may contribute substantially to increasing the number of STEM graduates—both by preventing leaks and by promoting STEM joining. Students who are taking STEM courses and are not STEM majors could be a potential source of STEM joiners. To increase the number of potential STEM joiners, STEM departments at universities could reconsider their curriculum design and offer more STEM courses for non-major students and perhaps require these courses to be taken early in students' careers. By doing so, students majoring in non-STEM fields would have the opportunity to experience STEM courses. Our results suggest, in fact, that these students may enjoy and do well in these early STEM courses. This experience could change their perception of STEM and revise potentially destructive false beliefs about lack of competency or preparation.

In this regard, we note that there is substantial variability across colleges and universities as to when students are required to take STEM courses. Some colleges and universities may require some STEM courses as part of the core curriculum, which is typically in the first year of college. This early exposure to STEM might increase the chances of the STEM-joining trajectory beginning. Moreover, universities can also consider establishing more joint degree programs between STEM and non-STEM majors, to increase the number of STEM adders, and therefore ultimately increase the number of STEM joiners. (Blinded) University's dual degree programs, in communication and engineering or in music and engineering, are good examples of this practice.

Conclusion

This paper presents and illustrates a developmental pathway for STEM joiners: when viewed in a broader, developmental context, we see that joining STEM and leaving STEM are often related. The decision to join STEM in college is often viewed by the students as part of a larger trajectory that includes their initial interests (e.g., in middle and high school) in STEM, followed by a decision not to pursue these initial interests in college. However, because of positive experiences such as doing well in STEM classes and encountering supportive mentors, the students revised the decision to leave and thus became what we are calling STEM joiners. They are not just joining; they see their journey as one of return to their earlier, "true" interest in STEM. Our results therefore highlight the value of examining the processes of entering or leaving a major from a developmental perspective that takes into account of the dynamics and fluidity in the adult development process (e.g., Arnett, 2009; Arnett, 2016; Murphy et al., 2010). The leaky pipeline implies a unidirectional flow—out of STEM. But considering the nascent and sometimes fragile nature of young adults' developmental trajectories, we were able to bring to light a non-linear pathway that emphasizes both leaving and returning. Thus, a developmental perspective can help to take us beyond reliance on the influential but often misleading metaphor and provide insights on a broader picture of students' development.

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Appendix A

Interview Protocol

Categories	**Example questions**
Demographic information	• What is your current major and what was your previous major? • Which year are you in school now? • When (which quarter) did you join STEM?
Pre-college	• Is STEM always something you wanted to do since you were young? • What did you want to do when you were a kid? • How were your science classes in high school? • Were you a science person in high school?
Decision process	• Why did you join STEM? • Did you take any STEM courses before picking up a STEM major? • Is there any specific person who played an important role in your decision process? • Can you walk me through your decision process of joining STEM?
STEM vs. non-STEM	• Do you think STEM majors are different from non-STEM? Why?

Note that the interviews were all semi-structured, which means we asked follow-up questions based on participants' responses to the questions on the interview protocol.

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Appendix B

Coding Scheme

Categories	Definition	Example
Dream/goal related to STEM	Students' pre-college experience regarding their dream and goal in STEM.	*"So I've always wanted to do something with science and math. I just, there were so many things in my way… So yeah I've always had that in the back on my mind."*
Lack of exposure to STEM in high school	Students' STEM experience in high school.	*"my high school was not really strong in the sciences... it was actually pretty strong in the social studies"*
Not a STEM person in high school/not well prepared	Students' self-perception in regard to STEM in high school.	*"I never thought I was good enough."*
STEM course experience	Students' college experience of taking STEM classes.	*"I took EECS 111 in the fall sophomore year and just had a really good time with it. It felt very comfortable to join the major after that."*
Supportive STEM environment	Feeling welcomed and being supported in STEM classes.	*"close your eyes… raise your hand if you think we're going too fast… raise your hand if you think we're going too slow… raise your hand if you think we're going just right."*
Mentoring from professors	Receiving advice and guidance from professors outside of class.	*"His passion about math was just kind of infectious…He was part of the reason that I even declared my math major…and I actually ended up emailing him a little bit after I decided not to do MMSS, just kind of asking him what kind of career paths, you know, people with a math degree."*
Mentoring from TA/graduate students	Receiving advice and guidance from Tas or	*"many graduate students offering their perspective... talking with me about what to do in life and also… I realized that some of*

	graduate students outside of class.	*them actually did have quite a bit of interest in the social sciences… and were able to talk about some of the issues and politics in society pretty well, and I was surprised by that. And I realized that… you are able to still maintain a strong background in the social sciences with the science major... so that's what I realized."*
Peer advice	Receiving advice from peer students.	*"I didn't know about this major until one of my friends, who is a year older than me, told me about the manufacturing design engineering major."*
Career consideration	Considering future career planning.	*"I bookmark articles all the time on my computer, and I just screenshot everything about, like, how there's someone right now going to uhh... the Silicon Valley to try to get people to go into defenses instead of going into, you know, these other industries within computer science. And I'm just looking at these, thinking I would love to do this."*
Family	Being influenced by family background or getting advice from family members.	*"My parents both came from very scientific backgrounds; they both went to medical school. I don't want to say influenced as in they forced me cause that sounds bad, but like... cause, like, if you're just surrounded by it and you're naturally curious about it, then you automatically have an interest in it… Yeah, they influenced me, but they didn't, like, push me or force me to do it."*

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RESEARCH REPORT

Excessive Mentoring? An Apprenticeship Model on a Robotics Team

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Abstract: *Participation on a robotics team affords students the opportunity to learn science and engineering skills in a competition-based environment. Mentors on these robotics teams play important roles in helping students acquire these skills. This study used an apprenticeship learning theory to examine how mentors on one high school robotics team contributed to students attaining the knowledge associated with designing and building a robot for competition. How active of a role did mentors play on their competition-based robotics team? How did mentors and students together handle the challenges they faced? The mentor-student interactions detailed in the research revealed an apprenticeship model where mentors played leadership roles reluctant to move beyond modeling tasks to students. The mentors' roles bring into question if they were granting their students the full opportunities to develop skills associated with working on a robot. Despite these developmental concerns, the students on the team gradually took up simple tasks working side-by-side mentors, saw expert engineers model professional habits, and expressed being inspired while contributing to a winning team.*

Keywords: *Apprenticeship, mentoring, out-of-school time, robotics*

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Introduction

Participation in robotics related activities points toward a potential for positive student outcomes in learning science and engineering skills (Benitti, 2012). Robotics is seen by some as a vehicle for learning and understanding new technologies (Barker, 2012) as students acquire engineering design (Ahlgren, 2002), electrical and mechanical engineering (Barak & Zadok, 2009), and programming (Williams, 2003) skills. Furthermore, robotics activities provide a hands-on experience (Mataric et al., 2007) that improves students' systems thinking (Sullivan, 2008), promotes scientific inquiry (Robinson, 2005), and increases awareness of scientific and engineering careers (McGrath et al., 2009). Adult mentors play instrumental roles on robotics teams by guiding students toward gaining scientific and engineering skills and supporting them through challenges brought on by robotics competitions and programs (Barron et al., 2008). This study examined mentoring, and the associated student behavior, on one robotics team where adult mentors used robotics as a means of passing down expert knowledge and engineering skills to a team of high school-aged students.

Mentoring is seen as an important factor in the development of less experienced individuals in many engineering and science fields. The mentoring process has been defined as a series of interpersonal exchanges between a more experienced individual providing support and guidance to a less experienced individual (Baugh et al., 1996; Spencer, 2006). Mentors can provide mentees with opportunities to take part in team building, brainstorming, and planning sessions (Russell, 2006) that contribute to the overall continuous learning processes within the engineering and scientific professions. Mentors can also create challenging and participatory learning environments (Atkins & Williams, 1995; McKinsey, 2016), provide feedback and suggestions for improvement (Quinn, et al., 2002), and integrate new members into social networks within an organization (Wallace, 2001) for their mentees. The mentoring process of giving advice and support has also shown to enhance a mentee's level of confidence and self-efficacy in their vocation (King et al., 2009; Kram & Isabella, 1985), including within engineering (Wallace & Haines, 2004). Students with mentors have the opportunity to observe their mentor being successful and assimilate these attitudes, behaviors, and values into their own practices (Fairbanks et al., 2000; Speizer, 1981).

Mentoring influences and impacts can also play out in out-of-school time (OST) robotics teams. A widely known, international robotics competition defines mentoring in a similar fashion: a process in which an experienced person provides guidance, support, and encouragement to a less experienced person (FIRST Mentoring Guide, 2007) in the context of designing and building a robot for competition. Mentors on these robotics teams have the potential of creating a challenging and participatory learning environment that promotes team building and work ethic while increasing students' level of confidence and self-efficacy in strategizing, designing, and building a robot.

This case study presents an approach used by mentors attempting to pass down scientific and engineering skills to their students on a robotics competition team. The findings from this study have the potential of contributing to the larger body of mentoring literature by describing one example of mentoring occurring in an OST environment. Additionally, the findings may inform researchers and practitioners in OST science, technology, engineering, and mathematics (STEM) education fields of some types of mentor-student interactions that take place in competition-based environments, and further the discussion of how the level of directive mentor involvement may impact student development in OST STEM programs.

The authors sought to address the following research questions:

1. How were mentors involved in helping their students through the processes of designing and building a robot for competition?
2. How did students behave and respond to their mentors' involvement?

Framework

This study turned to two learning theories to help illuminate the mentor and student experiences during their robotics season: traditional apprenticeship learning and cognitive apprenticeship learning theory. These two educational learning theories provided the authors with a lens with which to gain a greater understanding of how mentors and students on this single robotics team, which is referred to as Team Edison, worked together to accomplish their goals of designing and building a robot for competition.

Traditional apprenticeship

Traditional apprenticeship learning is often associated with on-the-job training of an apprentice becoming competent in a skill or craft that, in turn, contributes to the overall manufacturing and skilled labor workforce (Ainley & Rainbird, 2014). However, apprenticeship learning can be applied to less industrial contexts, including in OST robotics programs where mentors are guiding students how to use programming and construction tools. In apprenticeship learning, the apprentice is within close proximity of the context of practice (Johnson & Pratt, 1998) working side-by-side an expert mentor (Barab & Hay, 2001) learning a set of procedures or a specific skill. Traditional apprenticeship learning is known to have four stages: modeling, scaffolding, fading, and coaching (Collins et al., 1991).

In the modeling stage, the expert mentor demonstrates all of the desired learning goals and processes in front of a closely watching apprentice. In apprenticeship learning theory, most

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of the learning occurs during the modeling stage (Lave & Wenger, 1991) as the apprentice observes the requirements needed to successfully compete the task. In addition, the apprentice sees how an expert attack a real world task or problem without false starts or dead ends (Idol & Jones, 2013).

During scaffolding, the expert mentor provides varying levels of support as the apprentice begins to take ownership of the task. The level of support given by the mentor depends on the apprentice's zone of proximal development (Vygotsky & Rieber, 1988), or the difference between their ability to accomplish a task without help and their ability to complete a task with help. In this stage, the mentor must be aware of how much support the apprentice needs in order to successfully complete a task and progress forward in their learning. Providing too much support may prevent the learner from taking up tasks, while providing too little support may lead the learner to failure.

In fading, the transfer of responsibility from the mentor to the apprentice nears its completion. The master and apprentice continue to work side-by-side as the apprentice becomes more comfortable and confident in their ability to complete the tasks at hand. The master steps away from the master-apprentice interaction upon seeing the apprentice successfully complete the tasks, which then allows the apprentice to work independently.

In coaching, it is not so much a stage as it is constant monitoring by the expert mentor as their apprentice moves through the apprenticeship learning experience. The expert mentor monitors the apprentice's learning throughout by providing feedback, asking questions, offering encouragement, and challenging them with new tasks. The stages and aspects of traditional apprenticeship learning carry important implications for how learning can occur when a novice is learning new skills and content. As data were collected and analyzed, traditional apprenticeship learning theory was drawn upon to guide the understanding of how mentors on Team Edison were passing down skills and content to their students as the team designed and built their robot for competition.

Cognitive apprenticeship

It is important to note that traditional apprenticeship learning, where an apprentice learns under an expert's tutelage, can be enhanced to reach deeper cognitive levels in what is referred to as cognitive apprenticeship (Collins et al., 1989). In a cognitive apprenticeship, practitioners or expert mentors actively work to help the apprentice better understand the reasoning behind why they perform tasks in certain ways and how the work relates to other settings and contexts. More specifically, expert mentors make their thinking visible by pointing out possible pathways at decision junctions, best choice and practices at these junctions, and problems that could arise if certain actions are taken (Collins et al., 1991). Cognitive apprenticeship can allow the apprentice to understand the purpose of the knowledge they are learning, become informed about the different contexts in which the knowledge can be used, and ultimately use or apply the knowledge as opposed to passively receiving it (Dennen & Burner, 2008). As this model can help apprentices develop valuable higher-order thinking skills, this case study was particularly interested in the extent to which this style of cognitive apprenticeship occurred, if at all, on Team Edison. As the study drew upon traditional apprenticeship learning, it also drew upon cognitive apprenticeship to guide further understanding of how mentors and students were interacting with each other as they worked side-by-side in their science and engineering workspace within an OST robotics competition-based activity.

Methods

Team Edison was examined as a qualitative case study investigating their mentor involvement, mentor-student interactions, and associated student behavior (Hartley, 2004; Rossman & Rallis, 2012). One-on-one interviews and first-person observational data were collected during the same robotics season over the course of four months. The process of choosing Team Edison as the point of study involved a whittling down of ten other teams based on the degree of directive mentor involvement in the day-to-day decision making process of the robot design, construction, and implementation. Based on the findings of the larger study, Team Edison stood out as having high directive mentor involvement when it came to these decision-making areas. In addition, Team Edison aligned with educational learning theories in which students were learning and gaining experience from their mentors through an apprenticeship learning environment. For these reasons, Team Edison was chosen as a case study to examine how mentors were involved in passing down scientific and engineering skills to their students, and how their students responded on their robotics competition team.

It is important to note that all three authors have had experience mentoring students in OST science and engineering competition programs. Both first and second authors were public high school science teachers and organized OST STEM programs for their students. The third author has had experience being a lead mentor of an elementary and middle school robotics team for seven years. These experiences provided all three authors with a working knowledge and understanding of the framework of an OST competition program.

Participants and team settings

Pseudonyms were used for the names of the mentors, parents, students, and the teams who participated in this study. Team Edison consisted of 30 high school student members and 15 mentors. The Team Edison mentors were comprised of mechanical engineers, machinists, retired teachers, and computer programmers. Many of them held full time positions in local engineering and technology firms, but volunteered their time to help Team Edison in the afternoons and

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evenings. The lead mentor, the only teacher amongst the mentors, taught several computers programming courses at the high school, and led the overall operations of the robotics team after school. She held a bachelor's degree in information technology and an MBA from a university located in the northeast Atlantic area of the United States. Students joined the robotics team for a variety of reasons, including liking science and engineering, preferring competition-based activities, and wanting to be with their friends. All students who expressed a desire to be on the team were welcomed to join.

Team Edison was located in a suburb of a large city in a central Atlantic state. This veteran team of seven years was a school-based team, meaning the robotics team was an after-school extra-curricular activity option for all attending high school students. The team worked in a set of three rooms within the high school. The three rooms consisted of a large computer lab with several whiteboards for design discussion, a workshop with equipment and tools used for construction, and an open room where replica pieces of the game were housed and used for practice. The design, programming, and marketing teams spent most of their time in the computer lab. The build team received information from the build and programming team, but spent their time in the workshop. The large open room was used as more finished robot products needed to be tested.

Team Edison engages in an annual competition administered by a not-for-profit company. This company develops a different game each year where thousands of teams around the world create their own robot to play in the game. While the company mergers STEM content, sporting competition, and pop culture into the design of their annual games, their goals are more focused on youth development. Their central mission is to inspire K-12 students to enter careers and be leaders in STEM fields by engaging them in mentor-based robotics programs that build scientific and engineering skills and encourage innovation.

Each robotics team competing in this event, including Team Edison, was given six weeks to design and build a robot. Team Edison met every day after school for three to four hours. The game rules do not require teams to build the same robot but rather provides opportunities for teams to develop their own strategies and robot designs. This made for multiple variations of robot strategy, design, and construction across the entire robotics landscape. Upon registration, teams are given the minimal amount of materials to build a robot, such as motors, metal, and wheels. However, teams could spend up to thirty-five hundred dollars on additional materials to enhance their robot. Veteran teams had a material advantage over more rookie teams as they had accumulated materials and resources from prior years. Teams were required to enclose their robot in a giant plastic bag and time tag it at the end of the six-week build season to ensure fairness. These bags were then checked at regional competitions as a method of monitoring any wrongdoing.

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In the year of this study, the robotics game involved scoring points in two separate ways on a 27 by 54-foot field. Teams could design a robot to pick up foam basketballs off the ground and shoot them into one of four baskets located on both ends of the field. They could also score points by designing a robot that balanced on a teeter-totter bridge located in the center of the field. Most teams designed their robot to score points in both methods. In each match, a three-team alliance competed against another three-team alliance. Individual teams were placed on a different three-team alliance for each proceeding match in order to play with and against most teams in the competition. Individual teams prepared for their next match in their assigned pit area away from the playing field. In the pit area, mentors and students made adjustments and preparation to their robot in order to be ready for their next match.

Team Edison's robot design included the ability to drive straight over foam balls on the ground, scoop them up into a vertical conveyor belt made of surgical tubing, and shoot them out the top of the robot from a single spinning wheel. The balls were forced out the top of the robot from being wedged between a curved piece of metal and the spinning wheel. As the balls left the robot, they had a backspin that was advantageous for shoot balls off a backboard into a basket. Additionally, the robot possessed a camera atop their shooting apparatus to recognize the reflective tape on the basketball backboards in order to align and shoot accurately.

The not-for-profit company goes to great lengths to make the competition events just as exciting as the build challenge itself. Dozens of regional events are played around the world as teams choose which ones to attend. Teams may attend more than one regional if they have the budgetary means. Team Edison participated at two regional competition events, each consisting of approximately 60 teams. Team Edison also competed at the world championship event due to winning the "best overall team" award at one of the regional competitions they attended. Four hundred teams competed at the world championships.

Data sources and analytical approaches

The authors sought to shed light on a "contemporary phenomenon in a real-life context" (Yin, 2009, p.73), which is appropriate with descriptive case study methodology collecting data through direct observations and in-person one-on-one interviews. In attempting to compare data to a framework, the authors searched for matching patterns between the traditional and cognitive apprenticeship learning theory frameworks and the mentoring styles and associated student behavior data. While data were compared for similarities with the learning theory frameworks, analysis also looked for contradicting data. The type of triangulation took the form of data triangulation (Bryman, 2011) from sources such as observations, interviews, and student artifacts in order to increase the validity of the study.

Observations were recorded to capture events, actions, and interactions made by mentors and students on Team Edison as they designed, built, and competed with their robot.

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Observations focused on aspects associated with how Team Edison made decisions and completed tasks during the build and competition season: mentor involvement, mentor-student interactions, and student behavior and actions. The observations were made during the team's six-week build season, over two regional competitions, and at the world championships. Team Edison allowed the authors full access to team meetings during the build season as mentors and students completed tasks in their respective workspaces, held large and small group discussions about progress being made on the robot, and addressed issues that arose during the team's progression. The public nature of the regional and world championship competitions further allowed authors to gather close observations and data. This overall embedded approach produced a comprehensive data collection generating thick descriptions of the social processes that took place between the mentor and the students on Team Edison. Eight hours were spent observing Team Edison during the build season. The team was further observed at two regional events during the competition season. Sixty hours were logged observing the team over four days at two regional events and over three days at the world championship event.

Interviews were also conducted to gain an in-depth understanding of Team Edison's season progression. Specifically, the aggregate of individual mentor and student perspectives from these interviews helped elucidate mentors' role and involvement, mentor-student interactions, and student responses to their mentors' directive as the team progressed through designing, building and competing with their robot. Interviews were conducted on a one-on-one basis using a semi-structure approach (Drever, 1995). A list of prefigured, open-ended questions was developed to explore topics related to answering the case study's research questions. However, the interview process remained open to pursue topics the mentors and students brought up during questioning. All interviews were conducted during Team Edison's build season meetings and at competitions in order to capture real time data: mentors and students not far removed from their work. The lead mentor and four additional mentors were interviewed. Six students from Team Edison were also interviewed. Two students were chosen by the lead mentor to be interviewed, for they, as she pointed out, held leadership positions on the team. The other four students were interviewed at the world championships and had various positions on the team. The interview format began by requesting interviewees to explain the robotics game, share their team's strategic approach, and describe their robot design. These initial requests allowed interviewees to display their knowledge of the game and their team's direction moving forward. Then, the interview progressed into questions regarding the team's organizational structure and their role on the team. Questions in this part of the interview explored how the team was structured, what their individual roles were on the team, what their motivation was for joining the team, and how knowledge was passed from mentors and advanced students to more novice students. Additionally, questions in this part of the interview asked interviewees to

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describe the mentor philosophy and involvement, and how the mentor involvement influenced the organizational structure and day-to-day functionality of Team Edison. The final part of the interview looked into how the robotics competition influenced their own development. These final questions explored what interviewees gained from participating in the robotics competition, how the robotics competition had influenced their career views, and how they judged their performance at the end of the year. All interviews were recorded, transcribed, and confirmed by the interviewee to ensure accuracy of what was said in the interview.

The act of combining the traditional and cognitive apprenticeship learning theory frameworks created two themes that were used to organize, analyze and explain the data to support answers to the research questions. The two themes were *boundaries and objectives* and *apprenticeship stages*. Coding for the theme *boundaries and objectives* involved combing for descriptions in the data of mentors and students describing their goals, objectives, working boundaries, and level of involvement during decisions made on the robot strategy, design, and construction. For example, if a student described in an interview their role on the team, then this was coded as *boundaries and objectives*. Coding for the theme *apprenticeship stages* involved combing for data describing how knowledge and skill development was being passed down from the mentors to the students. Furthermore, coding within this theme looked for descriptions of the modeling, scaffolding, fading, and coaching stages as well as mentors providing reasoning behind why they performed tasks in certain ways during these transfers of knowledge situations. Evidence from these two themes was used to answer the stated research questions.

Findings

The following section presents the research findings as they relate to how mentors were involved on Team Edison in helping their students through the processes of designing and building a robot for competition, and how students behaved and responded to their mentors' involvement. In the first "Build Season" subsection, the two themes (*boundaries and objectives* and *apprenticeship stages*) are discussed along with evidence to answer the research questions as mentors and students worked to prepare their robot during the six-week build season. In the second "Competition Season" subsection, the two themes are, again, discussed in relationship to the research questions as mentors and students participate in the two regional competitions and at a world championship event.

Build season

Team Edison experienced the same intense challenge as every other team in the competition to develop a game strategy, create a robot design, build their robot, and be ready for competition within a six-week time period. The analysis of Team Edison during their build season revealed mentors playing active roles while creating a structured learning environment that allowed students to follow specific steps and assigned tasks. The working environment, influenced by the mentors' professional engineering background and the competitive nature of the robotics activity, afforded students opportunities to acquire skills in a more procedural manner while observing a robot being designed and built as it was intended. These findings mostly aligned with the traditional and cognitive apprenticeship learning theory frameworks as mentors modeled and scaffolded (Collins et.al., 1991) desired learning goals and processes to their students while providing reasoning and context to their decision making. However, latter stages of apprenticeship did not materialize as mentors were found reluctant to fade from students working on vital steps of the robot's design and construction. The learning theory frameworks are continued to be referred to as the findings are discussed and interpreted within the two coding themes.

Boundaries and objectives. The mentors on Team Edison believed their roles were to model proper design and construction techniques, create a workspace that resembled working in an engineering-like environment, and pass down their expert knowledge to the students. They believed that developing a robot design and constructing it provided them with a medium to show and teach students science and engineering skills. The mentors' expressed beliefs aligned closely with what we expect to see in apprenticeship learning theories (Collins et al., 1991) as expert mentors begin passing down knowledge and skills by first, modeling best practices and then, allowing students to slowly take over responsibility through guidance and scaffolding. Karen, the lead mentor, best illustrates the overall role that mentors play on Team Edison:

> Having mentor involvement on our team allows students to get an understanding of building a working robot. The mentors show them how things are done in the way they are intended to do. They are the experts. They show them and the students see how things are done by the experts.

A further description of the mentors' involvement entailed them wanting to broaden their student's understanding of scientific and engineering workplace habits as a whole. Their goals were to showcase a working environment that resembled how engineers work together in the hopes that these habits would trickle down to the students. Justin, a mentor of three years, describes this more detailed role of a mentor on their team:

> I think our role is to show habits of being an engineer. You know, come up with a design and a prototype. Test things out. Rethink a design before building a final robot. We want to show these habits and show what it is like to be an engineer and work with other engineers. I am hoping by showing these habits that they'll begin using these habits themselves.

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Mentors on Team Edison also wanted to share their own personal expertise as a way of contributing to the team. Many of them viewed themselves as a liaison, or a link, between what is happening in the real world of science, engineering, and technology and what their robotics team was trying to accomplish. Mentors felt that students were not only learning new skills from them, but also learning up-to-date techniques and information. Ken, a mentor of two years, shares this view of contributing to the team:

> I have had experience working with a similar shooting device as we have on our robot, and I know other mentors have other experience too. Part of our job is passing down what we know and what we know how to do to the students. If I have worked with some new equipment or technology, I want to make sure I share that with the team so they are familiar with it too.

In addition to sharing their expertise, the mentors held a desire to expose their students to all areas of robotics team, which included the build, programming, electronics, design, drive, marketing, website, and community outreach sub teams. They believed having their students spend at least some time in each area would help the students create a broader picture and understanding of how an organization worked. To ensure this happened, mentors rotated students around from sub team to sub team when they felt like the student had learned enough or became comfortable with responsibilities within their current sub team. Grant, a student in his fourth year on the team, shared the rotating process and its effects:

> The lead mentor's goal is to push you out of your comfort zone. She puts you into other groups once you have become comfortable in an area. I was on the build team for a while and then I got moved to help with our team's presentation. I am not good at speaking in front of others but it did help me get better.

While there was high directive mentor involvement on Team Edison, there was willingness on the mentors' part to share and teach design and construction skills to their students. Furthermore, the students on the team had a positive reception to the approach the mentors were using in their day-to-day operations. Abby, a high school senior and three-year veteran student, supports this positive attitude toward the mentors' approach:

> We get to see expert mentors right in front of us work and we get to see and learn from professionals in the way things are supposed to be done. They come right from their jobs to here and help us. Then we get to drive this amazing robot at competitions.

The students described their experience on the team as working collaboratively with their mentors, being exposed to increasing challenges, and seeing how things are done properly by

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professionals. Sean, a three-year veteran student, explains the process of how mentors and students work together:

> They work side-by-side us, which I think is good. They work with us and they treat us as their peers as opposed to being completely far removed and saying, 'We're not going to touch the robot. You guys go do your thing.' It's more like they work alongside us as team members almost which is really cool because obviously, they have more knowledge.

Some students provided detail as to how they were incorporated into more mentor initiated tasks, as shared by Sean in the previous statement. This mentor-student exchange continued as students became more familiar and confident with the task at hand before receiving more difficult challenges. These stated descriptions from the students align with early stages of apprenticeship learning theories as expert mentors demonstrate what they are working on while simultaneously enfolding less experienced students into working on the robot and expecting the students to begin learning the displayed skills so that they can eventually accomplish the tasks on their own. Ryan, a four-year veteran student, confirms these early stages of apprenticeship of students being brought into working on the robot and being given more responsibilities:

> Once you get comfortable with what they are showing you, you're given more to do. As you get more experience you start greater and greater tasks, but they are not going to give something that is way over your head to begin with but they are going to challenge you.

Along with having a positive disposition toward how mentors were interacting with them on their robotics team, many students appeared to echo the mentors' own definition of involvement. Students expressed that they were watching and learning how things were done correctly by professionals. Ben, a rookie team member, states this exactly: 'We get to see how things are done by the mentors and learn from what they are doing.'

Statements made from mentors and students on Team Edison regarding characteristics of their roles and involvement were in parallel with each other, appeared to not generate any conflicts, and mirrored apprenticeship learning theories of mentors modeling learning goals before students were integrated into the working process. Mentors acknowledged that they were the ones passing down vital information for their team to be successful. The students agreed with this process of first, watching expert mentors and then, slowly taking up responsibilities to become more integrated on the team.

Apprenticeship stages. The mentors on Team Edison created a structured learning environment that had students following procedural steps to acquire skills. These observational findings aligned with early stages of the apprenticeship learning theory framework as mentors

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modeled and scaffolded desired learning goals. Though, as these mentor-student interactions continued, mentors failed to fade and allow the students to work independently particularly when it came to tasks pertaining to the robot's design or construction. The highly active role and presence by the mentors caused a deviation away from the apprenticeship learning theories.

To illustrate mentors not completing the stages of apprenticeship learning by not giving students the freedom to work independently, the findings turn to an interaction that occurred between one of the build team mentors and a student after the mentor discovered a problem with their robotics frame.

Bill, one of the build mentors, noticed part of the frame needed some small reshaping in order for it to fit around the electronics board and drivetrain. Specifically, there were eight metal corner pieces that had a curved inside to them that needed to be reshaped. Once corrections were done, these pieces were to be fitted onto long horizontal and vertical metal pieces to make the lower section of the robot frame. Bill gathered the eight metal pieces and asked Max, a build team student member who had just finished listening to another mentor explain how the shooting apparatus would work, to join him at the bench grinder. Bill asked Max if he had used a bench grinder before. Max shook his head 'no.' In response, Bill nodded and told Max that they were going to reshape the corner pieces for the robot's frame. Bill placed the first corner piece on the tool rest in front of the grinding wheel and asked Max to watch closely because he wanted Max to be able to do it on his own. As Bill began to model how to grind down the curved corner piece, he began to orally explain what was happening. He referenced the angle the tool rest was set at and speed of the wheel as the metal receded from the grinding. When Bill finished making a more right angled corner piece, he pointed to other parts of the bench grinder to explain its scope and uses, including polishing metals and sharpening tools. Then, he said to Max that he'd like him to try grinding the next piece. Bill stood next to Max and gave specific instructions in order to replicate the second piece to match the first corner piece. Once Max finished, Bill took the metal piece and compared it with his piece to check if they lined up. This interaction of Bill guiding Max through the grinding process and then checking Max's work repeated itself with the remaining six pieces.

Several components of traditional and cognitive apprenticeship learning (Collins et.al., 1991) were present in the interaction between Bill and Max. Bill began by asking Max his level of familiarity with the bench grinder. This allowed Bill to gauge where to start and how much he needed to explain. Bill then took the time to orally describe what was occurring and the reasoning behind his approach while simultaneously modeling grinding the corner metal piece. In this early part of the interaction, the modeling of tasks by an expert mentor occurred while a novice stood by watching and learning (Lave & Wenger, 1991), as seen in traditional apprenticeship learning. An expert mentor was also observed adding context to the task by making the reasoning behind

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his actions visible and providing a broader scope of the equipment's uses (Collins et al., 1989), as seen in cognitive apprenticeship learning. Then, the interaction moved into the next phase as Bill and Max switched positions. Bill provided scaffolding and direction as Max completed the task of grinding the second corner metal piece. This scaffolding component is present in apprenticeship learning as a novice begins slowly taking ownership of the task in the presence of an expert mentor. The interaction continued as Bill remained working side-by-side Max providing constant guidance and advice. In this final phase of the interaction, the expert mentor did not fade to allow the novice apprentice to work independently. Here, a deviation away from the expected latter apprenticeship stages occurred as the mentor was reluctant to fade, and instead stayed to ensure each step was performed correctly. The skills learned by the student in this interaction focused on becoming accustom to using the equipment or tool, but did not expand to an application of skills in other contexts. Finally, the interaction runs parallel with statements made by both the mentors and students: a mentor brought in a student to show him what he was working on; a mentor modeled the task before challenging the student to perform the task himself; the mentor and student worked side-by-side.

This deviation from later apprenticeship stages repeatedly played out in mentor-student interactions that involved working directly on the robot's design and construction. However, all apprenticeship learning stages occurred in mentor-student interactions on Team Edison in areas not directly impacting the robot's design and construction, such as on the marketing and website development subteams. The following interaction displays how mentors faded from a group of students to allow them to work independently.

Karen, the lead mentor, was discussing with three students about the importance of marketing the team at the competitions so that when it came time for the elimination rounds there was a greater likelihood that their team name would be mentioned in conversations. Karen started showing them how to make team buttons that would be used to generate brand name recognition throughout the competitions. She showed how the images were laid out several times in a Word file before printing out many copies. Once one sheet was printed, Karen took the copy and cut out one of the images, placed it between a metal button and the plastic covering, and then laid it on the button maker machine to be hand pressed. She pressed down the handle, lifted it back up, and took out the button to reveal the finished product. She then asked the students to make a couple hundred of them for the team's trip to their two regional events. As the students began making the buttons, she monitored the students' progress for two or three buttons to ensure accuracy. Finally, before stepping away, she encouraged the students to think of other creative ways of marketing the team, and reminded them of previous years' shirts and buttons. Karen moved on to another project as the students made buttons and talked openly about their ideas to further market the team. The students quickly came to an agreement that they wanted to stand out and be recognized but not be obnoxious or annoying in public. Several ideas were shared before they decided on a professional look where everyone would wear a short sleeved collared shirt that had their logo on it and a small fedora hat decorated in sequins and blinking lights.

Most components of traditional and cognitive apprenticeship learning (Collins et al., 1991) were present in the team marketing interaction between the lead mentor and the three students. Karen modeled making the buttons and provided some scaffolding and guidance as the students took control of the task. Karen also faded from the task allowing the students to work independently and challenged, but did not require, the students to further think of ideas to expand their marketing roles. Observations made of mentor-student interactions during the build season, and later in the competition season, saw mentors playing more active roles in decisions and tasks that were directly associated with the robot design and construction. These mentor-students interactions during decisions made on the robot design and construction focused on student learning of machinery or tool competency skills. However, students were found to take more control of tasks and generate ideas in areas of the team that did not directly impact the robot's progress.

Competition Season

Team Edison competed against approximately 60 teams at each of the two regional competitions and, after qualifying, against 400 teams at a world championship event. The analysis of Team Edison, as they prepared their robot and competed in match play, revealed mentors playing an even more active role compared to during the build season. Mentors reverted to only modeling tasks to students and abandoned giving reasoning or context behind decisions they made, revealing a further deviation from the traditional and cognitive apprenticeship learning frameworks.

Boundaries and objectives. The mentors on Team Edison continued to believe their roles were to model tasks for their students during the competition season. Mentors modeled programming and mechanical adjustments while assigning small errands and responsibilities to their students. Erik, Team Edison's pit area mentor, captures what roles mentors and students have at the competitions:

> It works out that every mentor has their role at the competition. There's so much going on to get ready for the next match that we need to assign jobs to students, but we're getting them excited about the process and problem solving of the robot by showing them so they can see how it's done and be ready for the next match.

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Students provided their perspective of being on Team Edison at the competitions as committing to mentors demands, recognizing some pressure to win, and being goal oriented and responsible for completing tasks. Abby, the veteran student, describes the student roles at the competitions:

> It is a lot of pressure because we have gone to Worlds every year since our inception. You're thrown into this place where it's like you don't really know what's going on but our mentors help guide our team and keep us on track. [Team Edison] can be competitive, and it can be a stressful environment, but it's also a family… It is competitive, but it is very much so that you're with mentors and students that you know want to be there, who you know are working hard. It can be a bit stressful, but it is a good thing because it pushes you to succeed.

Statements made from mentors and students on Team Edison about their roles during the competition season described mentors managing the team's operations. However, despite mentors playing a more active role on Team Edison, students expressed a desire to continue working in this environment. Sean, the veteran student, shares his thoughts on the team's operations:

> I'm inspired by being on this team to go into engineering. Our mentors have their own jobs in engineering but come share with us how things are done and we build a great robot that helps us get to worlds [championship]. That's inspiring to me that I get to be a part of this and makes me want to go into engineering.

As seen in the next *apprenticeship stages* section, further evidence is given that align with the observations of mentors modeling robot adjustments and preparations between matches prior to informing students of changes as they drive the robot in match play.

Apprenticeship stages. There were clearly defined roles and boundaries between the mentors and students during the competitions. Through the apprenticeship learning theory lens, mentors were observed only modeling tasks for students and did not progress to scaffolding or fading stages. Students received relayed information from their mentors about any adjustments made to their robot prior to driving it in match play. The following interaction describes the roles mentors and students played in the time between matches.

After driving their robot in match play, students would place it on a handcart and wheel it back to their designated pit area and inform the mentors of any issues they had during their match. The pit area mentor would begin checking for any damages or mechanical issues as students stood by ready to aid the mentor. If students did actively participate, it was in the form of handing a tool to the mentor or running to look for a specific part from another team. Once any

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mechanical repairs or adjustments were made, the robot was wheeled by the students to the practice area to check for any programming and driving errors. Both the mentors and students prepared the robot to test its ability to scoop up balls and shoot them into baskets in the practice area. Mentors checked their programming language and tested the robot's shooting ability. One or two students would stand by the programming mentors while other students fed foam balls to the robot and retrieved them as the robot kept shooting. Once the mentors were comfortable with the robot, they would relay to the student robot drivers any new information or adjustments made that would affect their ability to drive or perform properly in the next match. The students would then reload their robot onto their handcart and wheel it over to the queue for their next match. The students would drive and compete in their match and the above process would start over again.

In these between match play interactions, the mentors and students were working as a team but had clearly defined roles: the mentors prepared the robot and the students drove it in match play. In the pit area, mentors modeled best practices of how to check for and repair mechanical damages for their students. Students were not further brought into the learning process of taking over tasks, as seen in apprenticeship learning theories (Collins et al., 1991). In addition, mentors completely abandoned adding any reasoning behind their decisions and how the work related to other contexts, as seen in cognitive apprenticeship learning theory (Collins et al., 1989). Mentors and students worked together to set up their robot in the practice area before, again, mentors modeled best practices of checking for programming errors and accurately firing balls from the robot's shooting mechanism. Finally, mentors transferred information to students on a need-to-know basis before the students departed to drive their robot in the next match.

Although there were open lines of communication between mentors and students, most notably students informing mentors of problems and mentors informing students of changes, mentors spent little to no time training students or explaining how to solve problems that arose during competitions. As seen in this next interaction, mentors continue to model problem solving, but do not further engage students into either explaining the reasoning behind their decisions or developing problem solving skills.

Team Edison made some modifications to their robot before participating in their second regional competition. In addition to the camera on top of their robot that recognized reflective tape on the backboards for shooting accuracy, they added a second camera near the base of their robot to allow the student drivers to receive a live feed on the computers in front of them for better driving visibility. Unfortunately, Team Edison soon found out the addition of the second camera caused the original camera on top of the robot to lose its ability to recognize the reflective tape on the backboards while the driver camera only received spotty reception. In a lengthy delay between two of their matches, six mentors and two students were at the practice area trying to

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solve the two cameras problem. Most of the mentors focused on checking the programming language on their computers while the two students and one mentor checked the robot to see if all equipment was properly connected and aligned. After approximately twenty minutes of the mentors talking amongst themselves, they appeared to become frustrated and decided to ask for technical help from a couple of adult competition officials. The conversation that ensued occurred between the mentors and the officials as the two students stood off to the side watching and waiting. The officials diagnosed that their robot was using too much bandwidth to accommodate both cameras. They suggested, talking directly to the mentors, to either reduce the frames per second on the driver camera or to take the driver camera off altogether and drive by normal sight. The mentors decided to reduce the frames per second feed for the next match before removing the camera completely if the problem continued. The mentors then made changes and informed the students they would be receiving a slower feed in the next match. The mentors told the students to rely on the computer feed only if they could not drive by normal sight. In the next match, the issue had been resolved as Team Edison returned to shooting accurately.

This interaction highlights the roles mentors and students played in order to solve a problem. The mentors took command of the situation by checking and rechecking where they felt the problem existed. Students played a minor role early on attempting to help by voluntarily attending to the robot. As time passed, mentors decided no one on their team was capable of solving the problem so they sought out help from technical officials. Once the officials diagnosed the problem, the mentors gathered the needed information, made a decision to fix the problem, and informed the students of the change to prepare them for the next match. When seen through the apprenticeship learning frameworks, the students that were present only watched how adult mentors attacked a real world problem (Idol & James, 2013). This interaction is also in line with other observations of the mentors on Team Edison playing major roles in preparing the robot and not moving beyond modeling tasks, while students observed tasks being completed and driving the robot in matches.

The deviation from the apprenticeship learning theories was more pronounced during the competition season as mentors and students did not progress through the stages of traditional apprenticeship learning and contextual and reasoning factors of cognitive apprenticeship were not present. Regardless of whether the mentors were incorporating students into completing tasks, as seen during the build season, or reverting to only modeling tasks during the competition season, the students on Team Edison saw expert mentors moving through an engineering process that resulted in a well-built robot. These mentor-student interactions also lead to the team performing well in match play and finishing in the top 50 teams at the world championship.

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Discussion

Some may form conjectures as to why the mentors on Team Edison did not attempt to create a more self-directed learning environment, where the locus of control over learning is transferred from the mentors to the students (Abdullah, 2001; Kerka 2000): the mentors desired to win in the competition-based robotics activity; the time constraints prevented in-depth learning; the adults lacked the pedagogical knowledge to further engage students in learning more complex design and construction tasks. Regardless of such speculation, the mentors on Team Edison maintained their position that student learning would mostly occur through their own modeling of design and construction techniques, workplace behavior, and decision making processes. This centralized focus on modeling can have positive workplace results. Modeling is an instructional strategy in which an expert demonstrates a new concept or approach to learning (Eggen & Kauchak, 2001). It allows expert mentors to engage their students in imitation of particular behaviors that complete tasks successfully and encourage learning. Modeling also helps mentors measure the difficulty of the task by giving focus to their students in what is expected of the workload and behavior (Haston, 2007). As Bandura states (1977), learning would be exceedingly laborious if people had to rely solely on the efforts of their own actions to inform them of what to do. In addition, effective modeling optimizes the chances of students having a successful learning experience (Biggs & Moore, 1993).

It appeared the students on Team Edison were in agreement with the more modeling approach used by their mentors. The associated student behavioral gains on the team were foundational workforce characteristics, including an acquisition of basic knowledge and skills, a recognition of accurate techniques and decisions, an awareness of their potential success, and an inspiration to further develop themselves in their field of choice. The mentors approach provided their students an insight into how professional scientists and engineers successfully complete tasks in designing and building a successful robot. The mentors also created a working environment where students were compliant with the assigned tasks given to them. In turn, the student experiences on Team Edison inspired them to continue to pursue their interest in STEM related fields: a central mission of many OST STEM programs.

In contrast to the initial benefits of modeling, the mentors’ actions of deviating from apprenticeship learning limited students’ further development beyond acquiring basic science and engineering skills. Students were given opportunities to observe their mentor being successful, but were provided with few opportunities to assimilate these attitudes, behaviors, and values into their own practices (Speizer, 1981), especially when working directly on the robot. The students participated in a hands-on experience (Mataric et al., 2007), and became more aware of scientific and engineering careers (McGrath et al., 2009). However, students were rarely given opportunities to explore their own robot strategy and design ideas. Mentors integrated students into the social and working networks within the team (Wallace, 2001), but only created a participatory learning environment that involved following directions with little need for providing feedback and suggesting improvements (Quinn et al., 2002).

Hovering, a technique mentors on Team Edison used to ensure accuracy, is an over-involvement of a parental or authority figure in a young person's life with the goal of avoiding negative consequences (Ginott, 2003). The mentors on Team Edison continued to hover and make important decisions throughout the build and competition season, thus protecting students from dire failure. This raises long-term developmental concerns, as students who report over-involvement of a parent or authority figure in their lives also report significantly higher levels of anxiety (Reilly & Semkovska, 2018) and lower levels of confidence when attempting to manage life's stressors (Bronson & Merryman, 2009). Furthermore, students who report having an over-involved parent or authority figure are related to extrinsic motivation to learn, perfectionistic discrepancy, and avoidance goals for learning (Schiffin & Liss, 2017), which have been associated with lower academic performance.

Grit, defined as a non-cognitive trait associated with perseverance and passion for long-term goals (Duckworth et al., 2007), is stated as an important personality indicator to determine one's ability to work through obstacles and challenges. An individual who possesses grit persists when faced with adversities, and those that face adversity and setbacks are said to reach higher levels of strength, fulfillment, and personal development (Haidt, 2006). The students on Team Edison were not given opportunities to work through difficult challenges, and thus concerns are raised about their long term ability to problem solve and sustained interests toward STEM careers. A parent or authority figure's involvement in their child's or student's academics is associated with increases in their child's or student's enthusiasm toward education (Henderson and Berla, 1994). However, a parent or authority figure can overplay their responsibilities, thus reaching a critical level that is detrimental to their child's or student's development and long-term fulfillment.

Conclusion

The overall analysis of the interview and observational data displayed mentors playing active roles to create a structured learning environment for their students. The high directive mentor involvement on Team Edison resulted in students conforming to the mentor-led workplace as they completed predetermined outcome tasks and responsibilities. The students were also shielded from failure as mentors ensured a successful robot was built for competition. These findings diverge from the central characteristics of traditional and cognitive apprenticeship learning theories: that learning can occur through modeling and explaining best practices,

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scaffolding to the learner's ability, and transferring the locus of control to the learner (Dennen & Burner, 2008).

The findings clearly show a truncated apprenticeship model as mentors did not fully progress through either traditional or cognitive apprenticeship learning pathways with their students. There was a strong presence of mentors modeling tasks for students, occasionally enfolding them into working directly on the robot while providing context behind their decisions and scaffolding to ensure the student's success. The short-term benefits of the mentors' actions resulted in students acquiring basic skills, the robot working properly, and students seeing success and being inspired to pursue a career in a STEM field. The long term concerns raised by the mentors' action include questioning the students' sustained ability to work through problems, level of confidence in dealing with complex situations, and long term trajectory toward a STEM career.

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RESEARCH REPORT

Gender and the STEM Fields in Education- and Career-Related Discussions between Finnish Parents and their Adolescent Children

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Abstract: *Occupational gender segregation in Finland is high and persistent in the fields of science, technology, engineering, and mathematics. Previous research has concluded that, rather than differences in aptitude, gendered educational and vocational choices originate from more complex system of attitudes, self-concepts, motivations and both direct and indirect social influences, all of which shape young people's future goals. In the sphere of social influences on career choice, parents play a special role in adolescents' education and career exploration. This study explores two interrelated areas: firstly, the ideas expressed by Finnish adolescent children's parents about the role of gender in education and career choices, and secondly, parent-child discussions about such ideas, especially with regard to STEM career pathways. The research data (N=103) was collected by means of an online survey. Almost half of the parents reported having had discussions about STEM careers with their children. Problematically, many parents considered that they had too little information about these careers. Our results indicate that mothers are more aware of the societal and individual consequences of occupational gender segregation than fathers are. The results also suggest that parents should be provided with up-to-date information on STEM careers and on the consequences of occupational gender segregation in order to enhance parents' readiness to support their children in their future exploration of education and careers. Greater collaboration between homes, career counseling, teachers and relevant organizations concerned with the economic world, working life and entrepreneurship would be beneficial in promoting awareness of these aspects during adolescents' career development.*

Keywords: *Career choice, gender segregation, parental involvement, STEM*

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Introduction

This present study aims to investigate how Finnish parents consider the role of gender in the education- and career-related discussions that they have had with their adolescent children, and how much parents know about career opportunities within the fields of science, technology, engineering, and mathematics (STEM). In addition, this study aims to shed light on how aware parents may be of the individual and societal consequences of occupational gender segregation.

In Finland, occupational gender segregation levels are noticeably high and persistent in the fields of STEM (Statistics Finland, 2018) despite the fact that Finland is one of the leading countries in fostering gender equality (European Institute for Gender Equality [EIGE], 2017a; United Nations Development Programme [UNDP], 2017). As early as in their secondary-level vocational education, female students are underrepresented in the fields of ICT and technology: in 2017 only 12 per cent of the new students who participated in education leading to vocational qualifications in these fields were women (Official Statistics of Finland [OSF], 2017a). In higher education, women orientate towards the fields of the life sciences more often than towards the physical sciences, applied mathematics, or engineering. For example, at the universities of applied sciences only 16 per cent of the students pursuing technology degrees in 2017 were women (OSF, 2017b). Science and engineering are among the principal occupations of Finnish men, while social work, healthcare and education are strongly female-dominant occupations (Statistics Finland, 2018).

Education and labour markets in many other egalitarian welfare states in Europe and in the USA have similar characteristics to those seen in Finland (EIGE, 2017b; National Science Foundation, 2017; U.S. Department of Labor, 2018). The employment of STEM-skilled workers is increasing, while a high number of people working in STEM fields will be retiring in the course of the coming decade (Caprile et al., 2015, National Science Foundation, 2019). The supply of a workforce does not meet the demands of the job markets in many countries because of an insufficient number of graduates in the fields of STEM and ICT. Too few young people are attracted to study STEM subjects or ICT, and the underrepresentation of women in these fields persists (European Centre for the Development of Vocational Training [Cedefop], 2016). While societies all over the world today rely on the development of science and technology, missing skills and labour input of women causes continuing concern in these fields. In Finland, the technology industry, chemical industry and forestry are the largest industries and their products account for approximately 80 per cent of Finnish exports (OSF, 2019). Hence, developing a sufficient supply of STEM-skilled labour is essential for maintaining and developing our well-being.

In addition to contributing to the inefficient functioning of the labour markets, occupational gender segregation has several other negative effects, both on individuals and at a societal and economic level. Gender segregation partially explains the gender gap in terms of wages since male-dominated occupations are often better paid than female-dominated occupations. Lower rates of pay can also discourage men from entering female-dominated occupations or from taking time off for family life. (EIGE, 2017b.). Prejudices about men's supposedly lower need for a work–life balance and job quality are also matters that have been posited as the consequences of segregation (Bettio & Verashchagina, 2009; Burchell et al., 2014; EIGE, 2017b). In general, occupational segregation can reinforce gender stereotypes and maintain gendered working life, as people choose careers which they have come to regard as suitable for their gender through observation of their environment (Bettio & Verashchagina, 2009, EIGE, 2017b).

Meta-analyses produced in recent decades of gender differences in science and mathematics performance have to this day shown that differences in abilities have narrowed and are currently quite small, while in some cases female students have outperformed male students in these domains (Else-Quest et al, 2010; Hyde et al., 1990; O'Dea et al., 2018). Research into gendered career choices has concluded that rather from differences in innate aptitudes only, gendered choices in STEM originate from a complex system of intellectual abilities, achievement motivations, the influence of family, school and peers, as well as sociocultural and biological factors (Wang & Degol, 2013).

Parental influence on children

In the sphere of social influences on career choices, parents play a special role in adolescents' education and career planning. Parents are typically the most significant people in the process of socialization, especially in relation to childhood, but they also play an important role in their children's adolescence, along with friends, teachers and other social influencers (Grusec & Hastings, 2016). Eccles' Conceptual model of parental influences on children (2014) concludes that parents hold specific beliefs and perceptions and expectations, such as perceptions of their children's competence and interests, which influence the kind of advice, equipment and toys, and experiences that they provide their children with. These behaviour patterns, in turn, shape children's beliefs, goals, and identities, as well as their expectations and values regarding various domains such as STEM (Eccles, 2014).

Parents' perceptions of students' abilities

Research has shown that parents' perceptions of their children's academic abilities depend on their children's gender (Jacobs et al., 2005; Jacobs et al., 2006; Räty & Kasanen, 2007). These perceptions are typically based on cultural gender stereotypes about boys' and girls' abilities in different domains (Jacobs, 1991; Jacobs & Eccles, 1992; Räty & Kasanen, 2007; Tiedemann, 2000). Parents who hold gender stereotypes concerning mathematics and science abilities are likely to underestimate their daughters' ability and overestimate their sons' ability in these domains (Räty & Kasanen, 2007; Tiedemann, 2000). The parents of girls have been found to place an evaluation on their children's mathematics abilities that is either lower or equal to boys' abilities even in studies in which the girls' actual achievement was the same or higher than that of the boys (Frome & Eccles, 1998; Yee & Eccles, 1988). Parents have also been found to think that girls' success results from hard effort rather than from actual ability (Frome & Eccles, 1998; Yee & Eccles, 1988), and that girls have to put more effort into achieving good learning results in mathematics (Frome & Eccles, 1998). Similar biases exist regarding parents' perceptions of their sons' and daughters' respective competence in the natural sciences. In a study conducted by Tenenbaum and Leaper (2003), for example, parents thought that science was less interesting and more difficult for

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daughters than for sons. In some studies, mothers have been documented holding more gender-stereotyped views regarding their children's' abilities than those of fathers (Frome & Eccles, 1998; Yee & Eccles, 1988).

There is a considerable amount of research evidence that parents' perceptions of their children's ability in science and mathematics have a significant influence on their children's self-perception in these domains (Bleeker & Jacobs, 2004; Frome & Eccles, 1998; Gunderson et al., 2012; Makwinya & Hofman, 2015; Parsons et al., 1982). Boys will often evaluate their own mathematics competence higher than girls will (OECD, 2015) and this has occurred even in studies in which girls achieved better grades (Jacobs, 1991). Studies have also documented that girls experience greater fear of failure in academic tasks in general than boys do (Alkhazaleh & Mahasneh, 2016; Mcgregor & Elliot, 2005). These kinds of self-perceptions impact on young people's school course selections and, later, their higher education and career choices (Bleeker & Jacobs, 2004; Correll, 2001; Eccles et al., 1999; Gunderson et al., 2012).

Parental support

Parental support plays a meaningful role in their children's self-perceptions regarding their abilities in, and attitudes towards, science and mathematics. Students who perceive greater social support for mathematics and science from their parents, teachers, and friends report better attitudes and have higher perceptions of their own abilities in these subjects (Rice et al., 2012). Parental motivational practices can also increase the likelihood of their children choosing science and mathematics courses (Harackiewicz et al., 2012), all of which enhance children's learning results and persistence in STEM careers later in life (Ing, 2014). In a study published by Dick and Rallis (1991), parents and teachers were perceived as influencing career choice more often for students choosing careers in engineering and science than for those not choosing such careers.

The study of Archer et al. (2012) showed that in developing and supporting children's science interests and aspirations, families' habitus (meaning family's everyday practices, values and sense of identity), and science-specific capital (referring to science-related knowledge, attitudes, experiences and resources), hold a significant power. Archer et al. found out that in families that had a "pro-science" habitus, it was typical that parents were holding science degree and/or were working within science-related fields, but also such "pro-science" families that lacked specific science capital, were able to utilize their existing resources in developing and supporting their children's science interest. In contrast, within families of lower socio-economic status, science is often less familiar and visible to parents' and children's everyday lives (Archer et al., 2012). Such families tend not to possess the same quantity and quality of resources to provide an equivalent basis for supporting the development of children's science aspirations (Archer et al., 2012).

Parents' lack of STEM career knowledge

Earlier research has indicated that parents may lack knowledge, and hence support that would help to motivate their children towards taking up STEM careers (Ing, 2014). In a study produced by Hall et al. (2011) the parents of high school students rated their knowledge of science, mathematics, engineering, and technology jobs and careers as weaker than their

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knowledge of other college- and career-related topics. Parents seem to be poorly informed about the opportunities that further education in STEM fields can offer (Organisation for Economic Co-operation and Development [OECD], 2008). In particular, parents with lower education may convey negative and stereotypical images of STEM professionals to their children (van Tuijl & van der Molen, 2016). Parents working in STEM fields themselves are, in turn, more able to dismantle stereotypes and inform their children about STEM opportunities since they have more knowledge of and are more familiar with both STEM work and STEM workers (van Tuijl & van der Molen, 2016).

Research aims

As addressed above, parents play a special role in the formation of their children's future education and career-related aspirations, and this also applies to gendered choices in STEM. Much of the past research has focused on parental beliefs concerning their children's academic abilities and on parental expectations of their children's success in academic and working life. However, little research has been done into how parents consider the role of gender in any of the education- and career-related discussions that they have had with their children, nor has much attention been paid to how much parents know about STEM career possibilities, nor into how aware they may be of the individual and societal consequences of occupational gender segregation. This study aims to fill this research gap by investigating parents' ideas regarding these aspects. Past research provides some evidence that children's science aspirations are largely formed when they are between 10-14 years of age (Archer et al., 2012). At the age of 10, gender differences are small compared to when children are older (Murphy & Beggs, 2005). Thus, we decided to study the parents of adolescent children, since this kind of investigation helps to develop innovatory interventions and educational materials supporting parent-child interaction at a level where they are undoubtedly necessary.

Hence, we plan to address the following research questions:

1. How much do parents think that their children's gender has influenced the education- and career-related discussions that they have had together?
2. How much do parents report discussing with their children the role played by gender in the choice of education and career?
3. From their own perspective, how well do parents think that they know about the career opportunities in the fields of science, mathematics and technology?
4. What kinds of views do parents hold of the consequences of occupational gender segregation in the fields of science, mathematics and technology?

Methodology

Data collection

A survey instrument (Trochim, 2006) was designed and implemented so that we could address the ideas held by the parents of Finnish adolescents about the various aspects listed in our research aims. In total, ten survey questions were constructed by a team of three researchers with the aim of filling the research gap that had been discovered after reviewing the earlier

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research on parental influence on education and career-choice and parents' STEM career knowledge presented in Introduction. It was discovered that there exist little research concerning parental self-reports especially on the influence of gender in educational and career-related discussions they have had with their children and on parents' knowledge on the consequences of occupational gender segregation. In the present study, parents' responses to five of these questions have been examined because their responses were discovered to be the most pertinent as sources of information related to the research questions investigated in this study.

These five survey questions were: a) do you consider that your children's gender affect any of the discussions that you have had related to their future education and careers? b) have you consciously discussed the influence of gender in making choices for future education or in choosing a career with your children? c) how well do you know about the educational and career possibilities in the fields of science, mathematics and technology?, d) to what extent have you discussed educational and career possibilities in the fields of STEM with your children?, and f) what kinds of consequences do you consider being related to occupational gender segregation in the fields of science, mathematics and technology? In the case of each one of these survey questions there were a comment box in which parents were allowed to write as long responses as they wanted. Even though questions a) and b) were basically closed-ended questions, each one of the parents' responses were more detailed than just "yes" or "no".

Sample

The survey was administered online, after which a link to the survey was sent to 17 middle school guidance counsellors. Middle school in Finnish education system refers to grades 7-9 for pupils aged 13 to 15. After middle school, pupils continue to the upper secondary level education and typically orient either to general upper secondary schools or secondary vocational institutions. (Finnish Ministry of Education and Culture, 2020)

The contacted school guidance counsellors were working in in our partnering school network. These partnering schools were public middle schools mainly alike, located in eastern Finland area. Eastern Finland area comprises of relatively small cities with population ranging between a few thousands to 93000, and the surrounding rural regions. Of the guidance counsellors, nine agreed to distribute the survey to their pupils' parents via school administration software. The guidance counsellors sent a link to the survey to all of their pupils' parents, of whom 85 mothers and 18 fathers eventually responded to the survey. The data was collected in the spring of 2017.

The age and academic background distributions of the mothers and fathers are presented in Tables 1 and 2, and, as the Tables show, a majority of the mothers and fathers had a university or polytechnic university degree, and a majority of them were 40-49 years of age.

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Table 1.
Age and academic background distribution of the mothers participating in the study (N=85).

Age/academic background	Comprehensive school	Upper secondary school	Vocational school	University or polytechnic
30-39	1	2	6	5
40-49	-	4	7	34
50-60	3	1	4	18
Total	4	7	17	57

Table 2.
Age and academic background distribution of the fathers participating in the study (N=18).

Age/academic background	Vocational school	University or polytechnic
40-49	4	6
50-60	-	8
Total	4	14

Data analysis

The survey data was analyzed by means of qualitative content analysis (Mayring, 2014). The analysis process started with inductive category development. Not all of the survey questions were adopted for analysis, but our focus was placed only on the questions that were relevant to research questions 1-4 (see p. 8). This kind of selection is considered permissible in the procedure of inductive category summarizing (Mayring, 2014). First, two researchers who were experienced in qualitative content analysis defined the categories individually by systematically reviewing all of the responses to the survey questions and examining the parents' ideas in the light of the research questions. In the case of each of the survey questions, they then defined the main categories of the parents' responses.

Following the first round of category development, a pilot loop (Mayring, 2014) was executed, which meant that the researchers revised their whole category systems and checked to find whether there were any overlaps and to ensure that the category systems suited the research questions. Finally, an intercoder check was implemented in which the researchers examined their definitions of categories together and compromised if there were any differences in their views. It was discovered that in the case of most survey questions the parents' responses fell quite clearly into yes/no/no opinion categories or scale-like categories. In the case of the question concerning occupational gender segregation and its consequences in the fields of science, mathematics and technology, eight categories were found to occur. The researchers classified as Other any of the responses that they considered to be either ambiguous or providing inadequate insight into the survey question.

The survey was performed in Finnish and the qualitative content analysis was conducted using the Finnish data. For the present study, the survey items and examples of the parents' responses were translated from Finnish into English only after the analysis had been completed so that the potential interpretations could be regarded as being as accurate as possible. The translations have been made by the authors, who have years of experience of translating different

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types of text from Finnish into English, and vice versa. The underlying idea with regard to the translations was to concentrate on intended meanings and readability, and the authors debated some of the potentially ambiguous cases in order to ensure the quality of the translations.

In the Results section, examples of the parents' responses have been presented in order to enable the reader to evaluate the analysis and to gain a better insight into parents' reactions to the survey questions. A statistical analysis was not made in this study as it was entirely qualitative, but to complement the reported data, the division of the parents' responses into categories is also presented quantitatively in the Tables in the results section.

Results

The results related to research questions 1-4 are presented in this section. First is shown how the parents' ideas of the influence of their children's gender on parent-child discussions about education and career choice. Next, there is a presentation of the parents' views regarding parent-child discussions of the influence of gender in education and career choices. And thirdly, the focus will be on the parents' self-evaluations of their own knowledge of STEM career opportunities and on their ideas about the consequences of occupational gender segregation.

The influence of adolescent children's gender on parent-child discussions related to education and career choice

At the beginning of the survey the parents were asked a closed-ended question about whether they thought their adolescent children's gender affected any of the discussions that they had had related to their future education and careers; in other words, whether they discussed the various career opportunities in different ways depending on the gender of their child. Table 3 shows the division of both the mothers' and the fathers' views into categories that resulted from the parents' responses. A majority of the parents considered that the child's gender had no bearing on the discussions. Nevertheless, eleven of the 85 mothers considered gender to have had an impact on their discussions.

Table 3.
Parents' views regarding the impact of their children's gender on the education- and career-related discussions they had had.

	Gender had no impact	**Gender had an impact**	**No opinion**
Mothers (N=85)	78%	13%	9%
Fathers (N=18)	94%	-	6%
Total	80%	11%	9%

The mothers who considered that gender had had an impact on their discussions justified their views by reporting that their children had gender-typical career interests and aspirations, as seen below (the number alongside the respondent is the consecutive numbering of the respondents retrieved from the survey data):

> "My sons have expressed very clearly that they are not interested in jobs in healthcare." (Mother3)

> "Most likely yes: gender has an impact. My sons are interested in the military and in aviation, which are quite male-dominant fields." (Mother4)

> "Yes, it [gender] does have an impact. My son has different aspirations from my daughter. The conversations with, and occupations of, relatives have also had an influence." (Mother90)

Views of this kind suggest that parents may not consciously steer the education- and career-related discussions with their children in gender-stereotyped directions, but if adolescents already have quite clear interests and aspirations, these may restrain their discussions with their parents, and the converse may be true with respect to other career pathway alternatives that may be challenging, especially if adolescents hold strong attitudes and stereotypes regarding jobs dominated by the opposite gender.

One mother who was unsure about the impact of gender thought that gender segregation in society might infiltrate into their education- and career-related discussions:

> "I would hope that it [gender] did not have an impact, but it is difficult to determine objectively. Our society is still strongly gendered, so the topic is inevitable in discussions, I guess." (Mother14)

Parents who denied that their children's gender had had an impact on their education- and career-related discussions justified their views by referring to the non-traditional choices that their children had already made. They also foregrounded their own generally encouraging approach to education- and career-related discussions and their non-stereotypical attitude to different occupations in terms of gender-appropriateness.

> "In my opinion, gender does not influence our discussions. One of my sons, for example, has chosen to orientate towards a traditionally female-dominated vocational trade. I did not try to guide him towards a more so-called masculine career pathway." (Mother98)

> "I have similar hopes regarding the future education of my son and my daughters – I want to support each of them in finding an educational pathway that will be suitable for their personalities. So, I don't think that our discussions have been different with each of them." (Mother21)

Some of the mothers and fathers denied that their children's gender had had an unjustifiable impact on their education- and career-related discussions, and some of the parents seemed to hold noticeably strong opinions about the topic.

> "It has not had any influence." (Mother64)

"No! It does not have any influence on our discussions." (Father3)

Parent-child discussions of the influence of gender in education and career choices

The parents were next asked if they had consciously discussed the influence of gender in making choices for their children's future education or in choosing a career with them. They were also asked to focus on the impact that they thought gender has had on educational and occupational choices. Over half of the fathers and a third of the mothers had not discussed the influence of gender with their children (see Table 4). One in three of the mothers and one in six of the fathers reported having discussed this topic with their children. There were several responses about which it was impossible to say whether there had been any parent-child discussions regarding the influence of gender. This kind of response has been placed in the *Other* category.

Table 4.
Parents' responses to the question of whether they had discussed the role of gender in education and career choices with their children.

	We have discussed this topic	We have not discussed this topic	Other
Mothers (N=85)	26%	36%	38%
Fathers (N=18)	17%	44%	39%
Total (N=103)	24%	38%	38%

The mothers who had discussed the influence of gender on educational and career choices with their children pointed out that they had talked about the particular challenges that girls might face if they orientated towards a male-dominant field. The mothers also suggested that they had had conversations regarding the physical requirements of certain occupations, women's conditions in working life, and the gender pay gap.

> Yes, I have discussed the influence of gender in education and career choices. The vocational education for auto mechanics, for example, is physically too demanding for a girl. (Mother19)

> Yes, I have discussed the influence of gender. Gender does not have any influence in education, but in working life it certainly has an impact. Women have to do more to prove their competence. (Mother10)

> In our discussions we have expressed the opinion that, in general, anybody should be able to do anything. One just has to have some kind of job. Sometimes, though, we have also discussed the pay gap that exists between men and women, and also which fields of work are female dominated, and so on. (Mother26)

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Some of the mothers and all of the fathers who had had discussions about the influence of gender in education and career choice with their children reported that they had emphasized to their children that gender should not have an influence on career choice.

> Yes, we have discussed this topic a bit. A chef can be a man or a woman, a midwife can be man or a woman, and so on. We do not think that gender has any influence. (Mother32)

> Gender should not have any influence, even though statistically it seems to have. In our discussions I have pointed out that everything is possible for both girls and boys. (Father59)

Career possibilities in the fields of science, mathematics and technology

The parents were also asked, in open-ended question format, to evaluate their own knowledge about the educational and career possibilities in the fields of science, mathematics and technology. It was found that, in terms of inductive category development, three categories matching the familiar scale Good-Mediocre-Poor were clearly visible in the views held by the parents (see Table 5). Only 18 per cent of the mothers evaluated their personal knowledge as good. Their evaluation of their knowledge was lower than that of the fathers, since 44 per cent of the latter regarded their knowledge about such jobs as being good.

Table 5.
Parents' self-evaluation of the state of their knowledge in relation to various different STEM educational and career opportunities.

	Good	**Medium**	**Poor**
Mothers (N=85)	18%	32%	50%
Fathers (N=18)	44%	39%	17%
Total (N=103)	22%	33%	45%

Many of those parents who evaluated their knowledge of career possibilities as good also reported having themselves gained academic or working life experience in those fields.

> I am very well aware of the career possibilities in these fields. I have a PhD in physics myself, and currently I'm an entrepreneur and a CEO. (Father14)

> Good (I have graduated in computer science myself). (Father22)

Parents who reported having only a medium level of knowledge concerning the career possibilities in such fields either reported being familiar with only the commonplace educational pathways or referred to the academic background or occupation of one or more of their family members.

> My wife has studied these subjects, and I have become acquainted with them in that way. (Father88)

In addition, a mother who rated her knowledge of these careers as poor referred to her inner circle:

> [I know] very little [about these jobs]. I have no experience of these jobs as far as the people close to us are concerned. (Mother20)

Parents' responses to this question suggest that their main sources of knowledge vis-à-vis STEM education and career opportunities are their own academic and working life backgrounds or those of their spouse, relatives or other individuals close to them. In this context, none of the parents mentioned the teachers, school guidance counsellors or any of the Finnish organizations that are focused on providing career information to schools and to citizens in general.

The parents were next asked about the extent to which they had discussed education and career possibilities in the fields of STEM with their children. The categories that the parents' responses fell into were reminiscent of the categories on the Likert scale (see Table 6). More than half of the fathers and almost half of the mothers reported having had this kind of discussions with their children either extensively or to some extent.

Table 6.
Parents' evaluations of the extent to what they have discussed different STEM education and career opportunities with their children.

	Extensively/ To some extent	**Very little/Not at all**
Mothers (N=85)	49%	51%
Fathers (N=18)	56%	44%
Total (N=103)	50%	50%

Parents who reported having discussed STEM education and career opportunities either very little or not at all with their children mentioned that this was because they had insufficient knowledge about such topics or even because their children were uninterested in STEM career pathways.

> We haven't discussed this topic, because I don't know much about it. (Mother13)

> Very little at the moment. Besides, I have too little information about the topic! (Mother34)

> The fields of mathematics and technology – we have not discussed these fields and my children are not interested in these fields, partly because they lack

> mathematical ability, I guess. My eldest child orientated towards agriculture (Mother36)

The parents' responses to this question support our speculations which the previous question had provoked. It quite clearly appears that parents are provided with too little STEM career information to talk about the jobs in these fields with their children. It is also concerning that the lack of interest and lack of abilities determine some adolescents' career aspirations at even the middle school level and shape their education- and career-related discussions at home.

Occupational gender segregation and its consequences in the fields of science, mathematics, and technology

Finally, parents were presented with an open-ended question concerning the nature of the consequences that parents think are related to occupational gender segregation in the fields of science, mathematics and technology. Parents were allowed to list as many consequences in the text box included in the survey as they wanted. Some of the parents mentioned only one thing, while some parents listed several consequences. The parents' responses could be divided into the eight categories presented in Table 7.

Table 7.
Parents' notions of the individual and societal consequences of occupational gender segregation in the fields of science, mathematics and technology, based on their prevalence.

	Mothers (N=85)	**Fathers (N=18)**	**Total (N=103)**
Gender pay gap	27%	1%	23%
National competitiveness and innovations	14%	1%	13%
Gender equality	9%	0	8%
Gendered career choices	8%	1%	8%
Advancing one's career	4%	1%	4%
Attitudes	2%	1%	3%
There are no consequences	22%	16%	21%
I do not know/No response	13%	56%	20%

The consequences of the various responses to gender segregation were distributed quite diversely in the parents' responses. It was, however, discovered that the mothers were able to mention more consequences resulting from occupational gender segregation than could the fathers. Every fourth mother mentioned the gender pay gap and every eighth mother mentioned the innovations or competitiveness of the Finnish nation. One mother also raised the problem resulting from cultural perceptions of what is appropriate for boys:

> Gender segregation still supports the division of occupations into male- and female-dominated occupations in our society. This leads to lower pay rates in female-dominated fields, while it also generally impacts on gender equality,

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which also in fact concerns men. If everyone could choose a career based on one's strengths and interests, we would be a happier and more innovative nation. It is still the case that boys cannot choose to do girls' things… I realized this yesterday, when my son was making his course selections for the eighth and ninth grades!" (Mother23)

With respect to this type of remark, only a few instances were observed in the fathers' responses. On the other hand, one of the fathers had covered gender segregation very thoroughly and analytically in his response:

> If gender segregation was caused by biological factors, I would not see it as problematic. In that case, it would be questionable to try to fix imbalances by setting gender quotas. However, because the strong imbalance most likely results from cultural factors, I consider it detrimental. The most urgent concern is that many girls who have talent in these domains [science, mathematics and technology] and could find their calling there, are not orientating toward these fields because they do not receive enough support, and because their environment or cultural stereotypes are pointing them in other directions, the teaching in those fields favors boys (the curriculum or teachers' attitudes) et cetera. Thus, it is essential that, regardless of their gender, people should be able to find the jobs that they are really excited about and really enjoy doing (regardless of gender roles etc.). If this happened and there was then very little gender imbalance in occupations, it would not be a problem. Currently, in the worst-case people do not find a rewarding job or career for themselves. (Father34)

This father recognized the cultural impact of a stereotypical education and career choices, which together constitute nowadays the dominant explanation for segregation is research, rather than biological differences between different genders, as we discovered in the Introduction of this study. This father also recognizes the detrimental effects of segregation at an individual level and also on the STEM fields that have to forego the inclusion of skilled female workers.

In general, the fathers who responded to the survey did not seem to consider occupational gender segregation to be a very problematic phenomenon.

> I don't know. There are hardly any significant consequences! The phrasing of this question is strange! (Father101)

Thirteen percent of the mothers and over half of the fathers answered "I don't know" or did not respond to the question at all. It is notable that a considerable proportion of the parents participating in the study did not know or did not perceive occupational gender segregation as having any societal or individual consequences.

> There is an imbalance between the genders in these fields. But does it matter? (Father11)

This finding makes it recommendable that, in addition to STEM career information, parents should be provided with the facts connected with the impact that gender segregation in these fields has on individuals, the economy, the environment and society, both in Finland and globally, in order to help parents, become more aware of the importance of discussing jobs in STEM with their children.

Discussion

This study investigated, firstly, the ideas expressed by Finnish adolescent children's parents about the role of gender in education and career choices, and secondly, parent-child discussions about such ideas, especially with regard to STEM career pathways. The results of this study contribute to the field of research on parental involvement in adolescents' career exploration in the aspect of STEM career pathways.

In relation to research question 1 on the amount that parents consider their children's gender having an influence on the education- and career-related discussions that they have had together, a majority of the parents participating in this study did not consider their adolescent children's gender to have an influence on the future education- and career-related discussions. The parents' responses mediated a consensus view that it is adolescents' interests and aspirations that guide their discussions. Parents seem to encourage their children to find an educational and occupational path that will suit their personality and interests, regardless of their gender. Some parents, however, reported that their child had noticeable gender-stereotypical aspirations, and as a consequence their child's gender to some extent restrained the education- and career-related discussions that they had at home.

What comes to the research question 2 on how much parents report discussing with their children the role played by gender in the choice of education and career, fewer than a third of the parents reported having discussions with their children about the influence of gender on educational and career choices. In many cases parents avoided mentioning such topics because they thought that other things mattered in education and career choices more than gender, and hence they did not include the gender aspect in their conversations with their children. However, many mothers reported talking about the challenges that girls, in particular, might face if they were to orientate towards a male-dominant field.

With regards to the research question 3 on how well parents think that they know about the career opportunities in the fields of science, mathematics and technology, the study showed that half of the parents had discussed educational pathways and potential careers in the fields of science, mathematics and technology with their children, even though especially the mothers also mentioned that they had only a poor knowledge of the jobs in these fields. The fathers evaluated their knowledge about careers of this kind more highly than did the mothers. What comes to the research question 4 on parental views concerning the consequences of occupational gender segregation in the fields of science, mathematics and technology, the mothers were able to refer in greater detail to the consequences that occupational gender segregation has on individuals and at a societal level. The mothers emphasized the gender pay gap and the problems in competitiveness at a national level, stressing that greater equality was the best way to discover the full innovatory potential of their country. Our study suggested that some of the fathers were almost dismissive of the problems associated with occupational gender segregation and its consequences.

With respect to discussion of the influence of gender in education and careers, it can be debated whether it would be more beneficial to recognize the reasons underlying gender-stereotypical education and career choices and then to promote gender-conscious discussions rather than to try to fade the gender aspect out of career planning. For example, one of the factors underlying girls' retention of STEM career pathways is their lower self-perception of their personal abilities in these domains. It would be beneficial to make parents aware of this fact and to give them tools to support especially their female children in building a stronger self-concept in science and mathematics. In addition, familiarizing adolescents diversely with different occupations, also with gender-atypical occupations, could be a gender-conscious way for parents to contribute to their children's planning for the future. In a study by Rice et al. (2012) students who perceived greater social support for math and science from their parents, teachers and friends displayed better attitudes and had higher perceptions of their own abilities in math and science. There are also several other studies in which adolescents who have made non-traditional career choices report feeling supported by their parents and teachers (e.g., Buschor et al., 2014; Dick & Rallis, 1991).

Even though our study suggests that parents do not think that gender has an influence on their education- and career-related discussions with their children, it is still plausible that parents hold gender-stereotypical beliefs and attitudes subconsciously. A study made by Jacobs et al. (2006) has demonstrated that parents' early gender-stereotyped expectations for their children's occupational achievements were closely related to the actual occupational decisions made by their adult children. Parents should be provided with information about this topic to make them more aware of the parental influence on course selections and career choices. Educational practitioners, such as guidance counsellors and subject teachers, should help parents and their children to conduct a critical examination of gender-stereotyped perceptions of occupations that may occur in their family, in their children's social groups or in the media. Thinking about traditional expectations and gender stereotypes concerning abilities and aptitudes would help both parents and their children to recognize and question widely-held beliefs that may be limiting children's choices regarding their future education and career.

In the present study, a relatively greater number of mothers reported having discussions with their children about the influence of gender on educational and career choices than did fathers, and mothers seemed to be able to mention more consequences of occupational segregation than could fathers. One has to, however, bear in mind that these findings raised only from the conversion of the qualitative data to a quantitative data presentation, and no statistical analysis was conducted in this study to see if the differences in mothers' and fathers' views were significant. There are some earlier studies that have suggested that fathers hold more traditional attitudes about gender than do mothers (Blakemore & Hill, 2008; Tenenbaum & Leaper, 2002) and are somewhat more likely to encourage their children into gender-typed activities (Lytton & Romney, 1991). On the other hand, the study published by Frome and Eccles (1998) suggests that mothers are more influential than fathers in terms of the extent to which girls develop gender-stereotypical views of their academic abilities. Another study, by Borrell-Porta, Costa-Font and Philipp (2018), suggests that fathers are less likely to hold traditional views about gender roles if they help to raise a girl. Future research should delve more into the role of fathers in adolescents' future planning, especially in the case of girls orientating towards stereotypically masculine fields.

Our study suggests that parents' knowledge related to STEM career pathways is quite limited and some parents stated outright that they did not know much about the STEM jobs and thus could not discuss them with their children. There are also a few other studies that have pointed out that parents may often lack knowledge and support to motivate their children towards STEM careers (Hall et al., 2011; OECD 2008). Concerning career education carried out in schools, it could be fruitful to include parental participation in some of the lessons and activities. In Finland, compulsory basic education has started to implement a revised national core curriculum in which entrepreneurship and skills for working life are two of the aims set down for transversal competences (Finnish National Board of Education [FNBE], 2014, p. 24-25). The curriculum now also focuses specifically on physics and chemistry with a view to increasing pupils' awareness of careers that require skills in these subjects (FNBE, 2014, p. 418, p. 424). Collaboration and interaction between STEM subject teachers and homes would be beneficial in this context as it provides an opportunity to simultaneously increase parental knowledge on STEM career pathways and harness parental influence on educational and career choices for the benefit of adolescents' STEM career aspirations. A study by Harackiewicz et al. (2012) has shown that a simple intervention consisting of brochures and a web-site aimed at parents that highlights the usefulness of STEM courses has enhanced both parents' and adolescent children's perceptions of the value of studying science and mathematics and has increased the likelihood of adolescents selecting courses in these domains.

Considering how big an impact middle school and upper secondary school course selections have in terms of further education and career, it would be important to take gender segregation issues into account with parents even at the earliest stages in their children's education. In Finland, advanced mathematics grades have become ever more emphasized in the application criteria not only in STEM fields but other fields as well, in terms of student selections. When adolescents are applying for STEM fields, their mathematics skills are also measured in the entrance examinations. If a young person is disengaged from mathematics and does not select advanced mathematics courses while in upper secondary school, it makes orientating towards higher-level STEM education more challenging. Helping parents to become more aware of this fact early enough is essential, since they can have a significant influence on supporting girls, in particular, who may have a lower mathematics self-efficacy but in fact considerable mathematical abilities to embark on STEM pathways. It would be especially important that parents with lower educational backgrounds should be targeted, since parents with higher educational backgrounds seem to be more aware of the importance of early interventions and they are more likely to place their children in STEM pre-schools and provide their children with extracurricular STEM activities.

The study that we have undertaken suggests that parents tend not to be particularly well aware of the consequences of occupational gender segregation nor do they consider segregation

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to be a problematic phenomenon. Yet, as mentioned at the start of this article, research concerning job markets and the economy in the European Union and in the United States suggests that occupational gender segregation has several individual and societal consequences, such as wage inequality and labour and skill shortages. Parents should be provided with up-to-date information about the problems that STEM fields are suffering and they should be better informed about the importance of educating a STEM skilled work force that will be able to deal with the challenges related to environmental issues and social and economic well-being both in Finland and globally. This should also be undertaken in a way that will help to make them better prepared to talk about jobs in STEM with their children and to promote conscious educational and career choices. Collaboration between homes, school guidance counsellors and relevant organizations operating in the area of the economy, working life and entrepreneurship may prove to be an effective way of promoting awareness of these aspects.

Limitations

One flaw concerning the validity of our results is that social desirability may have influenced some parents' responses when they were inquired if their children’s gender has an influence on the education and career related discussions. That is, some parents may have responded that gender matters very little because they believe that this is the "correct" response. Socialization into gender-typed career pathways in family context often occurs through subtle patterns of encouragement and discouragement, rather than explicit conversations about gender (e.g., Leaper, 2015) and parents may be unable to accurately self-report on the role gender plays in their socialization practices. Experimental or observational methods (e.g., Tenenbaum & Leaper, 2003) would be more appropriate methods for obtaining accurate information about parent-child conversations.

In the case of this present study, however, the aim was to construct a narrative from parents’ self-reports concerning these questions, and to discuss the responses critically in the light of previous research findings in the field of study. The aim was not as much to obtain totally accurate insight into the role of gender in parent-child conversations. We argue, that it is valuable to investigate parents’ subjective self-reports in this context as it provides an opportunity to reveal disagreements between parents’ ideas and previous research findings on the type of conversations they have with their children. This in turn, provides information on the needs of interventions targeted particularly to parents for making them more conscious and perhaps less euphemistic of their role in children’s gender socialization.

As far as the transferability of the results of this study is concerned, it should be noticed that the findings represent the views mainly of parents who have a higher-level academic background. Since past research suggests that parents with high academic background place a greater value on science and mathematics (Archer et al., 2012; Shin et al., 2015), our data may provide a more positive impression of parental awareness of both STEM job possibilities and occupational gender segregation than would a sample of parents with more diverse backgrounds.

On the other hand, all of the respondents were from the Eastern Finland area, which is regarded as one of the more rural areas of Finland, especially in comparison with the metropolitan area in Southern Finland. In Eastern Finland there are fewer STEM-related companies and organizations with which parents could have become familiar than is the case in

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the area in and around the capital, Helsinki. This factor may well have influenced parents' awareness of the diversity of STEM jobs as discussed in this study. Future research should control more parents' academic background influences on the education and career exploration with their children. Future research could also investigate the areal differences in Finland in parental awareness of both STEM occupations and the consequences of occupational gender segregation.

Additional limitation of this study was that significantly more mothers than fathers responded to the survey. It may be argued that this study is more a representation of the views of mothers with a higher-level academic background from Eastern Finland area rather than of the views of Finnish parents as a whole. It has to also be acknowledged that perhaps some of the fathers that responded in the survey were more gender progressive and involved in their kids' education, and some of them exceptionally critical concerning gender issues, which provoked them to take part in this study. Hence, the transferability of our findings concerning fathers' views must be evaluated very critically.

Conclusion

This study documents that Finnish adolescents' parents' knowledge related to STEM jobs and the consequences of occupational gender segregation is rather limited. There has been research in other countries too, that have indicated that parents may lack knowledge on these career pathways and thus lack of tools to motivate their children towards taking up STEM careers (Hall et. al., 2011; Ing, 2014). These types of results suggest that parents should be provided with more information on STEM career possibilities and on the consequences of occupational gender segregation in order to enhance parents' readiness to support their children in their future exploration of education and careers. Collaboration between homes, schools and relevant organizations concerned with the economic world, working life and entrepreneurship would be beneficial in promoting awareness of these aspects to parents.

Regarding future research, it would be interesting to examine the influence of children's gender on parents' responses in a survey similar to the one that was implemented in this study. Such a study could also be expanded by investigating simultaneously both adolescents' and their parents' views about the role of gender in education- and career-related discussions and in choosing careers in the fields of science, mathematics, or technology. In addition to investigating the influence of parent-child interactions in adolescents' education and career choices, future research should look more closely at other influences such as the encouragement given to subject teachers and guidance counsellors and also provided by peer-to-peer interactions.

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RESEARCH REPORT

Perceived Impact of COVID-19 and Other Factors on STEM Students' Career Development

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Abstract: *In early 2020, colleges shifted abruptly from traditional in-person to remote distant instruction due to COVID-19 potentially exacerbating science, technology, engineering, and mathematics (STEM) students' recruitment and retention. This preliminary study using survey methodology was conducted with STEM students at a small (700 students) private college to examine questions related to students' perceptions of natural science careers, career decision-making factors, barriers influencing students' career path, including effects of COVID-19 on career goals, mental health, and perceived quality of instruction. A Qualtrics® survey was sent to 180 STEM students, from which we received 53 responses (29.4% response rate). Consistent with other studies, family was one of the most important factors supporting their career path. Students had a relatively upbeat career outlook despite being in the middle of a global pandemic and were only moderately worried about the impact of COVID-19 on their future career. Despite these relatively positive outcomes, the abrupt switch to online instruction was viewed unfavorably by most respondents, who valued the hands-on learning experiences obtained with traditional in-person instruction. It is possible that respondents' views of online instruction may improve over time as instructors become more adept at using new instructional tools. Future research should evaluate this aspect and whether students' career goals change across time as the pandemic unfolds.*

Keywords: *STEM, career choice, COVID-19*

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Introduction

The coronavirus disease (COVID-19) was first reported in Wuhan, China during late December, 2019 and by March, 2020 quickly spread to become a worldwide pandemic (World Health Organization, 2020). In the U.S., state governmental bodies quickly acted to curb the spread of COVID-19 and reduce fatalities. Strategies included a massive shut down of the economy, reshaping of social interactions (e.g., wearing a facial mask and maintaining three meters' distance between people), heightened personal hygiene practices (hand washing, refraining from touching one's face) and increased sanitization of objects and surfaces, to name a few (National Governors Association, 2020). Higher than normal unemployment rates occurred in the U.S. due to the shutdown of the economy U.S. Bureau of Labor Statistics showed a record unemployment rate of 14.7% in April, 2020 (US Bureau of Labor Statistics, 2020). For college and university students, this situation presented specific challenges.

Particularly under the conditions at the time of this study conducted in May 2020 (i.e., pandemic, economic concerns, etc.), difficulties in mental health status such as depression, anxiety, and/or stress was a concern. Wang et al. (2020) conducted a large (N =1,210) anonymous online survey of the general public in China during January 31 - February 2, 2020. A third of their sample indicated that they were experiencing moderate to severe anxiety with college students showing significantly higher anxiety and stress scores on the Depression, Anxiety, and Stress Scale (DASS-21) compared to those employed. Students in the U.S. may be similarly experiencing high anxiety and stress scores during the pandemic as some research has found (Rudenstine et al., 2020).

University and college students living in dorms, eating in cafeterias, and attending classes together present circumstances ripe to foster the spread of the virus. To cut rising transmission rates during the pandemic, colleges and universities around the world shifted en masse from traditional, in-person to remote delivery of instruction (Regehr & Goel, 2020). These instructional changes may make students less confident about whether they can reach career goals, which may result in changes in students' career interests. In particular, these COVID induced changes in instructional format for science, technology, engineering, and mathematics (STEM) students, may reduce hands-on laboratory and field experiences. Reduced confidence in performance skills and self-efficacy may reduce confidence in attainment of career goals.

Investigating STEM students' career perceptions is important to ensure that sufficient numbers of students enter STEM fields to create an ample skilled workforce, increase research and development of innovations, and train the scientists needed to solve significant problems. Between 2010 and 2020, the U.S. Bureau of Labor Statistics projected an 18.7% increase in

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employment in all science and engineering fields. Biological, agricultural and environmental life scientists' employment projected an increase of 20.4% (STEM Education Data and Trends, 2014). Despite the lucrative career opportunities in STEM fields, enticing students to pursue a degree in science has faced challenges even prior to the pandemic. The National Center for Education Statistics (NCES) reported that between 2001 and 2018, 20% of all bachelor degrees were awarded in STEM fields. While the overall number of completed bachelor degrees had increased by 59% during that time period, health related professions showed a 12% increase and engineering and biological sciences fields each only showed a 6% increase (National Center for Education Statistics [NCES], 2020). To make matters worse for filling increasing opportunities in science and technology, Chen (2013) found an attrition rate of 48% of bachelor and 69% of associate degree students in STEM fields between 2003 and 2009.

Social cognitive career theory (SCCT; Lent, 2013; Lent et al., 1994) provides a framework for understanding the complex factors that may influence students' decisions to seek education and careers in STEM areas. Some of the main components proposed in the SCCT model include contextual factors, learning experiences, barriers, self-efficacy, outcome expectations, contextual supports and barriers leading to career performance and attainment of goals (Lent & Brown, 2019; Lent et al., 2000). Stemming from Bandura's (1986) theory, self-efficacy refers to a person's view of their ability to perform a task. Outcome expectations are the beliefs that certain career actions will have particular results (Lent, 2013). For example, being good at identifying different species of plants will lead to an environmental science career working outdoors and being in good health. Career barriers have been defined as "events or conditions either within the person or in his/her environment that make career progress difficult" (Swanson & Woitke, 1997, p. 446). Contextual forces (e.g., economic, family support, financial situation) may influence self-efficacy and then career choices and goals with an ultimate impact on performance and attainment of goals (Lent et al., 2003). Over the past 25 years, the SCCT model and its offshoots have received much research support (Lent & Brown, 2019).

Applying the SCCT model to the situation at the time of this study, COVID-19 and high unemployment represent contextual factors that may impact students' career goals and/or confidence in attaining that goal (Lent et al., 2000). The partial shutdown of the economy is another palpable and severe threat that may make certain STEM careers less appealing (e.g., health concerns) or unattainable (e.g., reduced financial resources). Outcome expectations related to employment availability may impact students' career interest. Under changing conditions during the COVID-19 pandemic, whether STEM students are confident in attaining their career goals and have the necessary support and lack of barriers to strive toward career goals is a question that needs to be addressed. Moreover, whether this milieu derailed the career interests of (STEM) college students has not been extensively studied.

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Conversely, the pandemic may be associated with positive student attitudes (e.g., questioning, curiosity, skepticism, creativity) and have a beneficial influence on STEM students' career development. COVID-19 poses a significant problem for science to solve and may be, for a STEM student, motivation for further study. Students may be intrigued by the research questions that the pandemic presents such as, how can zoonotic or animal-human disease transmission be reduced? Can vaccine testing be made more efficient? Additionally, the media's portrayal of scientists showcasing an understanding of the problem and possible solutions to COVID-19 may serve as a role model and promote STEM career interest and positive career outcome expectations (Lent, 2013).

The purpose of this descriptive research is a preliminary examination of STEM college students' career goals during transition to online instruction due to COVID-19. The following research questions were examined using a survey method with STEM students at a small private college:

1. What are students' perceptions of natural science career outcome expectations?
2. What general career decision-making factors are important in supporting STEM students' career/graduate school path?
3. What general barriers influence STEM students' career/graduate school path?
4. Is COVID-19 affecting STEM students' career goals?
5. How do students perceive the pivot to online instruction due to COVID-19 impacted their STEM courses and laboratory classes?
6. Are STEM students experiencing high levels of stress, anxiety, or depression?

Method

Participants

There were 53 respondents out of a total of 180 STEM students (29.44%) who received the announcement and answered part of the survey, which represents a 10% margin of error at the 90% confidence level. However, there were 38 (21%) who completed the entire survey. For those who responded, the sample consisted of 26 (68.42%) males, 11 (28.94%) females, and 1 (2.63%) questioning or unsure. The average age was 22-years-old ranging from 19 to 26 years. Ethnic/racial background included 36 (94.74%) white, 1 (2.63%) black or African American, and 1 (2.63%) Hispanic, Latino, or Spanish origin. The average cumulative grade point average (GPA) for those respondents who gave permission was 3.56, ranging from 2.55 to 4.00 with 4.00 the maximum possible. The major selected for over half of all participants was either Fisheries & Wildlife Services, Environmental Science or Natural Resources and Conservation Management majors (see Table 1). There were 36.84% (n = 14/38) who were first generation or had parents who never attended college.

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Participants' names were entered into a drawing for a $50 gift card upon completion of the survey as indicated in the study announcement. The College at Brockport-SUNY Institutional Review Board approved the study and participants provided informed consent prior to completing the online survey.

Table 1.
Number of respondents in each STEM major

Major	n	%
Fisheries & Wildlife Services Majors	13	33.33
Environmental Science	6	15.38
Natural Resources and Conversation Management	6	15.38
Forest Ecology Management	4	10.26
Biology	3	7.69
Ecological Restoration	3	7.69
Human Health and The Environment	2	5.13
Environmental Studies	1	2.56
Sustainability	1	2.56
	39	

Materials

The Qualtrics® survey contained a battery of measures, totaling 47 questions. Survey topic areas, in order of presentation, were career choice, important factors supporting career, barriers, effect of COVID-19, online instruction, mental health status, and demographic questions.

Career Decision-making. Career choice was assessed by asking respondents to select the occupation most closely matching their future desired career. Occupations listed as career possibilities from which to choose were based on those from the 2017 National Survey of College Graduates, National Science Foundation (NSF), United States Census Bureau. Additional careers were added in the natural science area.

The Engineering Outcome Expectations scale was utilized in this study (Lent et al., 2001; Lent et al., 2003). This scale assesses respondents' perception of what will be likely as result of a major in engineering with 10-items (e.g., do work that I would find satisfying) rated along a 5-point scale labelled as not at all likely, a little, moderate, quite, and extremely likely. In this study, the original question stem was modified by replacing the engineering major with natural science career path and an additional item was be able to maintain good health. Psychometric evaluation of the original scale suggests that it has good internal reliability and correlates with measures of task and coping efficacy, interests, and choice goals (Lent et al., 2003).

Career contextual supports and barriers were measured with a 17-item scale used by Haynes and Jacobson (2015) based on the widely used Perceptions of Barriers scale developed by McWhirter (1997). Respondents were asked to rate the degree of importance of each item for supporting their current career/graduate school path along a 7-point scale (e.g., mother, father, subject teacher, etc.). Additional items added to the list included internship experiences and

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service-learning experiences. Barriers for career/graduate school path (e.g., lack of family support, not knowing how to study well) were rated along a 7-point scale ranging from 1 (not a barrier) to 7 (very much a barrier). Adequate test-retest reliability and concurrent validity with career decision making self-efficacy, vocational skills self-efficacy, and outcome expectations has been found with the Perception of Barriers scale (McWhirter et al., 2000).

COVID-19 Impact on Career. Several questions were constructed to directly assess the possible effects of COVID-19 on participants' academic and career interest. These questions were reviewed for face validity by the authors and two students. One question concerned participants' perceived confidence in attaining career goals given the current health concerns (i.e., COVID-19) as measured along a 4-point scale labeled as extremely confident, moderately confident, slightly confident, and not at all confident.

Another question posed was to what degree has the COVID-19 pandemic impacted your interest in science using a 5-point scale labeled as extremely positive to extremely negative. If a respondent selected extremely positive then a question was asked about in what way(s) has the COVID-19 pandemic positively affected your interest in science. The respondent could check any or all items from a list for their answer to this question (e.g., presents a critical health concern to address, provides role models or heroes to emulate, demonstrates the usefulness of science for solving important problems, illustrates the importance of data for decision making, sparked interest in animal-human disease transmission (zoonotic), and other).

Respondents were also asked to what degree has the COVID-19 pandemic impacted their career goal, with a 5-point scale labeled as extremely positive impact, somewhat positive, no impact/unsure, somewhat negative impact, and extremely negative impact. If a respondent selected extremely negative impact, then they were asked, in what way(s) do you perceive that COVID-19 pandemic has negatively impacted your career goal. Various possibilities were listed for the respondent to select including cannot pursue my original career goal, financial, inability to concentrate on my studies, increase in negative emotions impairing everyday functioning (e.g., anxiety, stress, depression), difficulty with switching to online instruction, perceived reduced quality of instruction, and worry about one's college.

The survey also contained a question asking respondents to rate the degree to which they are worried about the impact of COVID-19 pandemic on their future career. A 5-point scale labelled as a great deal, a lot, a moderate amount, a little, and none at all was provided.

Online Instruction. A series of questions were asked about the respondent's online instruction experience including whether the individual had previously completed online college/university-level courses and, if so, how many. How has online instruction impacted their science classes and, in a separate question, their laboratory classes were also asked. Both questions used a 5-point scale labeled as extremely positive impact, somewhat positive impact, no impact/unsure, somewhat negative impact, and extremely negative impact.

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Mental Health. The Depression, Anxiety, and Stress Scale (DASS-21; Lovibond & Lovibond, 1995) was used as a screening tool to assess mental health status. Support for use of the DASS-21 as an assessment of general distress with young adults exists (Kia-Keating et al., 2018).

Demographic Information. Demographic information collected included age, gender, race/ethnic background, GPA, and major area of study.

Procedure

A descriptive research design with survey method was employed to gather information about respondents' career goals, career barriers and supports, impact of COVID-19 on career and science interest, mental health status, and demographics. The online survey was sent to 180 STEM students at a small (approximately 70 students) private college in upstate New York. The announcement to participate, with an embedded link to the Qualtrics® survey, was emailed by one of the authors prior to the end of spring, 2020 term on May 1, 4, and 12, 2020. Campus shut down and transition to online classes occurred March 23, 2020 under the directive of the Governor of New York such that students were exposed to online instruction for 5 to 7 weeks prior to completing the survey.

Scoring of DASS-21 responses by the researchers occurred within 24 hours after submission of the survey by a respondent. If a respondent's DASS-21 scores for depression, anxiety, and/or stress were in the severe or extremely severe range then a recommendation to access mental health services with a counselor's name and contact information was emailed to the individual.

Quantitative Data Analysis

Data analysis involved treating Likert-type scale data as interval measures. Descriptive statistics, including means (M), standard deviations (SD), and Pearson Product Moment correlation coefficients were used to summarize the data.

Results

Future career

Over half (59.6%, 28/47) of respondents identified biological scientist (e.g., botanists, ecologists, zoologists) or natural resources (e.g., fisheries technician, environmental technician, wildlife scientist, conservation scientist, land use planner) as their future career (Table 2).

Table 2.
Respondents' selection of an occupation that most closely matches their future desired career (N = 46).

Future Desired Career		Number of Respondents
Biological/Life Scientist	Biological scientists (e.g., botanists, ecologists, zoologists)	14
Natural Resources		14
Teacher-Pre-college		3
Consultant		2
Law Enforcement		2
Engineering		1
Technologist/Technician/Surveyor		1
Health Occupation-epidemiology		1
Lawyer/Judge		1
Green Construction Specialist		1
Wildland Fire/USFS Forestry		1
Technician		1
Zookeeper/Animal Care Specialist		1
Ecological Restoration		1
Law Enforcement/Ethics Advisor		1
Research Associate/Assistant		1
Service Occupation, Except Health		1
Manager, Tree Care Industry		1
Total		46

Respondents evaluated what their future career will be like on the Outcome Expectation scale, as seen in Figure 1. Many respondents perceived that it is extremely likely that their natural science career will allow them to experience satisfying work (54.6%, M = 4.3, SD = 0.8), do exciting work (40.9%, M = 4.1, SD = 0.9), have a career valued by family (38.6%, M = 4.0, SD = 1.1), do work that can "make a difference" in people's lives (38.6%, M = 4.3, SD = 0.6), feel that there are people "like you" in this field (31.8%, M = 4.1, SD = 0.9), and maintain good health (25.0%, M = 4.1, SD = 0.7). On the other hand, they were not at all likely to feel pressure from parents or other important people to change their major/career to some other field (59.9%, M =1.7, SD = 1.0) nor receive negative comments about their major/career from their friends (58.1%, M = 1.8, SD = 1.1).

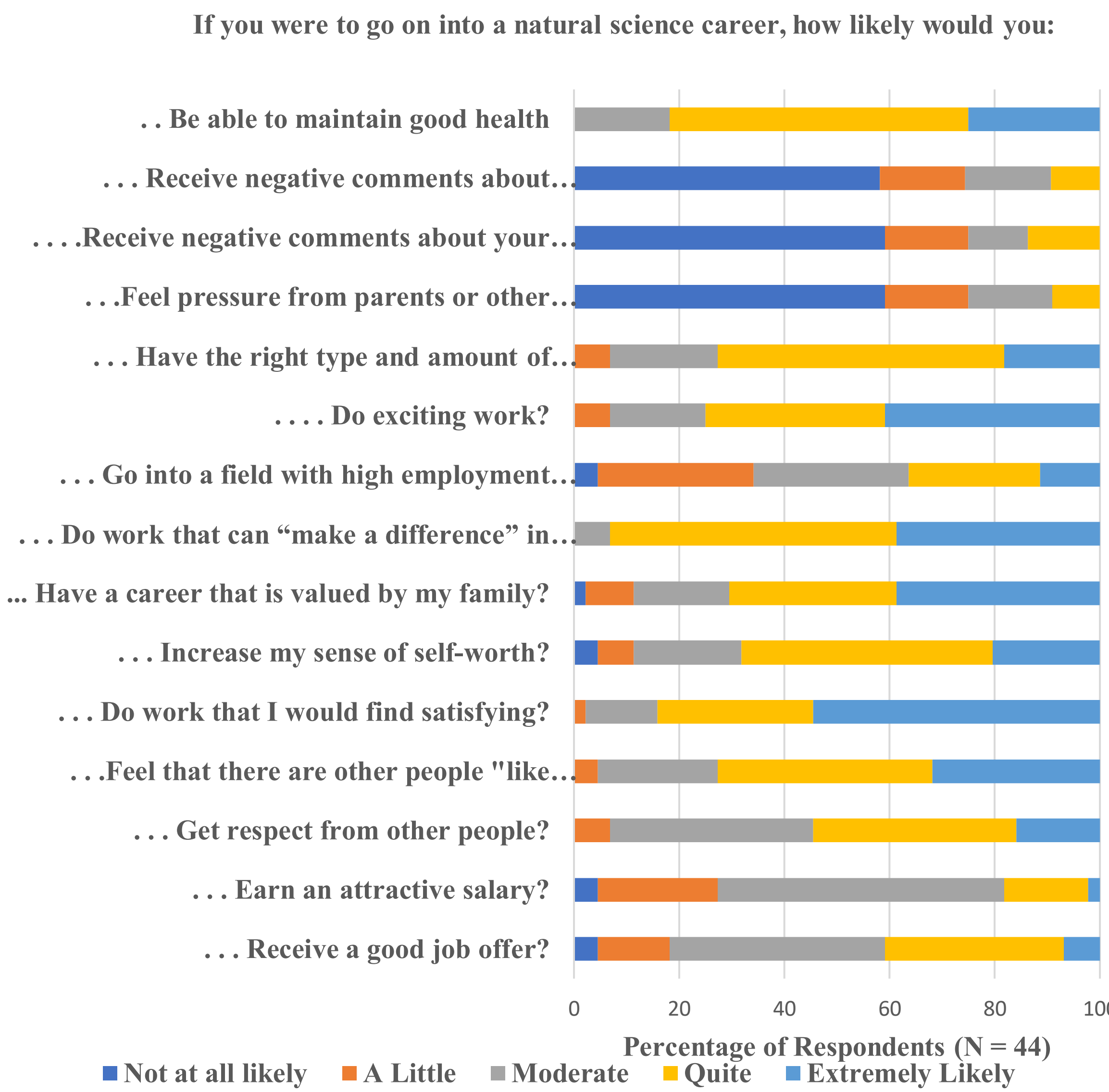

Figure 1. Percentage of respondents' ratings along a 5-point Likert-type scale of the perceived likelihood of various events and situations if they were to go on into a natural science career.

Using the Contextual Supports and Barriers scale, factors rated as very important by respondents include mother (43.2%, M = 5.2, SD = 2.1), knowledge about occupation (40.9%, M = 6.1, SD = 0.9), being naturally inclined (39.5%, M = 5.9, SD = 1.2), college teacher (34.9%, M = 5.2, SD = 1.2), science related classes (34.1%, M = 5.6, SD = 1.6), and father (31.8%, M = 4.8, SD = 2.1) as seen in Figure 2.

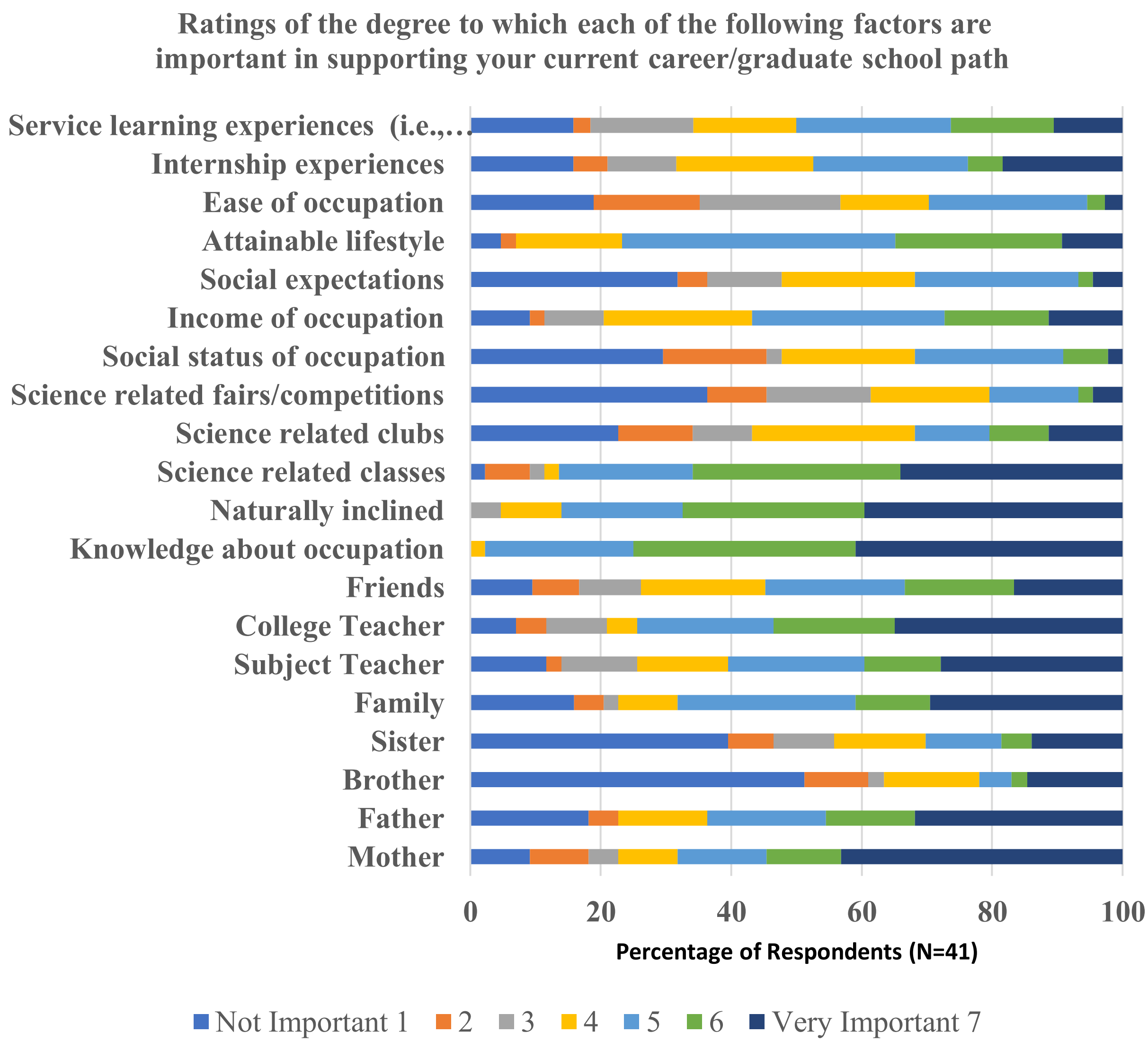

Figure 2. Percentage of respondents' ratings along a 5-point Likert-type scale of the perception of the importance of factors in supporting their current career/graduate school path.

Barriers for respondents' career/graduate school path were also rated (Figure 3). Overall, no item was perceived as a barrier for all and there were only a few barriers noted by many. The main career barriers identified by respondents were school is too expensive (M = 4.3, SD = 2.0), lack of financial support (M = 3.8, SD = 2.1), and lack of field experience opportunities (M = 3.2, SD = 1.9).

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Figure 3. Respondents' ratings along a 5-point Likert-type scale of the perceived barriers of various factors for their career/graduate school path.

COVID-19

Most respondents were moderately (41.5%) or slightly (26.8%) confident about attainment of their career goals in light of COVID-19 (M = 2.8, SD = 0.92) as seen in Figure 4, panel 1.

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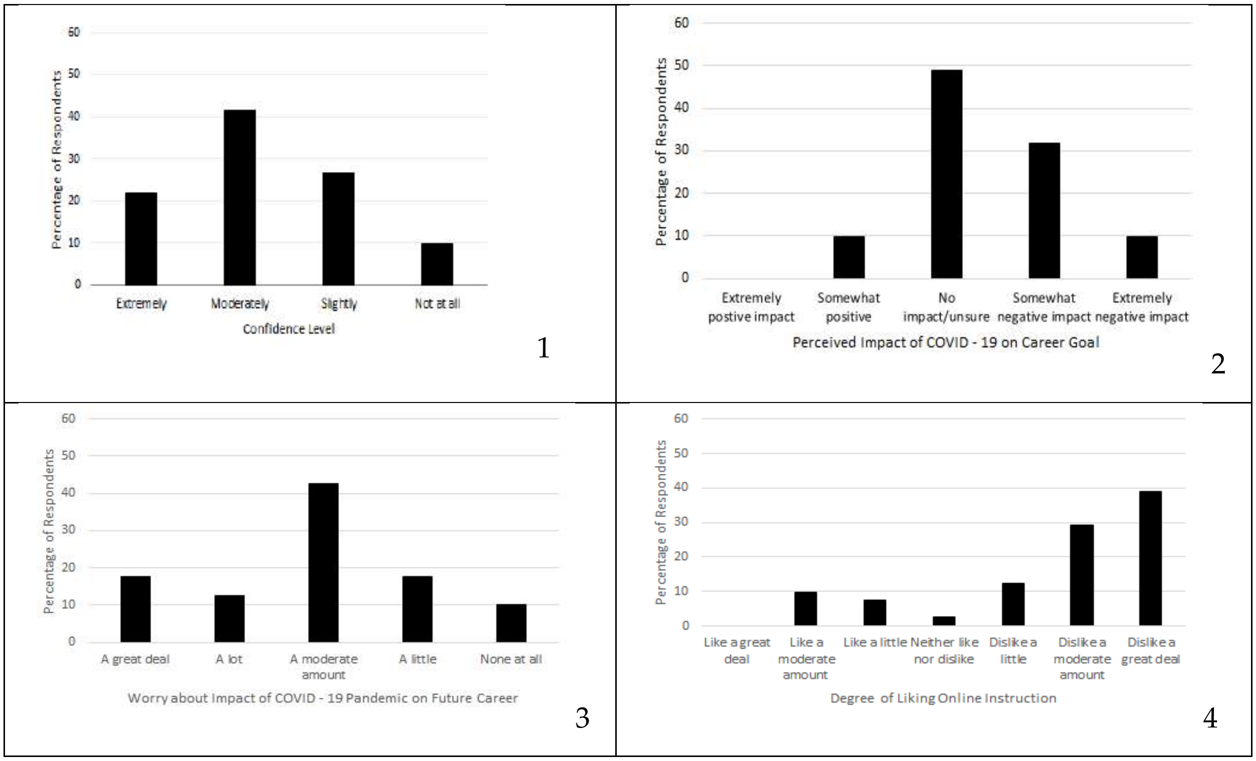

Figure 4. Panel 1. Respondents' degree of confidence in attainment of career goals, given the current health concern (i.e., COVID - 19). Panel 2. Percentage of respondents' ratings of the degree to which COVID - 19 pandemic impacted their career goal. Panel 3. Percentage of respondents' degree of worry about the impact of COVID-19 pandemic on their future career. Panel 4. Percentage of respondents' perceived degree of liking online instruction.

Regarding respondents' perception about the impact of COVID-19 pandemic on their career goal, no respondents were extremely positive and only 10% were somewhat positive (Figure 4, panel 2). Most respondents perceived that COVID-19 had no impact/unsure (48.8%, 20/41) or a somewhat negative (31.7%, 13/41) impact on their career goal ($M = 3.5$, $SD = 0.8$). For those who rated the impact of COVID-19 as having an extremely negative impact, reasons selected for why varied widely and, at most, three respondents indicated that it was due to an inability to concentrate on studies, financial reasons, perceived reduced quality of instruction, or worry about their college. One respondent wrote "Nobody is hiring due to the lockdowns, and all positions with relevant experience are full." Additionally, there was a negative association between ratings of confidence in career goal given COVID-19 and level of anxiety ($r(41) = -0.31$, $p < 0.05$). As respondents' confidence in their career goal increased, their anxiety decreased. Additionally, respondents' confidence in career goal given the current health concern (i.e., COVID-19) was positively correlated with likelihood of maintaining good health in one's future career ($r(41) = 0.37$, $p < 0.05$). As confidence in career goal increased, respondents rated being in good health higher.

The impact of COVID-19 on most respondents' interest in science was neither positive nor negative (68.3%) with 29% of respondents indicating somewhat or extremely positive impact. For those who indicated that COVID-19 had an extremely positive effect on their interest in science (12.2%), it was attributed to presenting a critical health concern to address (22.7%, 5/22), demonstrating the usefulness of science for solving important problems (22.7%, 5/22), and sparking interest in animal-human disease transmission (zoonotic) (22.7%, 5/22).

Only 10% of respondents were not at all worried about the impact of the COVID-19 pandemic on their future career (Figure 4, panel 3). Of the remainder, the majority (41%) were worried a moderate amount, while 30% were worried a lot to a great deal about the impact of the pandemic on their future career ($M = 3.1$, $SD = 1.2$).

Respondents' perceived COVID-19 impact on interest in science was positively correlated with internship barrier ($r(38) = 0.35$, $p < 0.01$). As respondents' ratings of interest in science increased, a greater perception of a barrier of internship experiences occurred.

Participants' perceived impact of COVID-19 on their career goal was negatively correlated with confidence in career/graduate school path such that, as COVID-19 impact increases, confidence in one's career/graduate school path decreases ($r(38) = -0.36$, $p < 0.05$.

Online Instruction due to COVID-19

There were 68.3% (28/41) of respondents who had previously completed online college/university courses prior to the current term. Most respondents disliked online instruction a moderate amount (30%, 12/41) or a great deal (37.5%, 16/41) (Figure 4, panel 4). Regarding the impact of online instruction on science classes, most perceived it as somewhat (52.5%, 21/41) or extremely negative (32.5%, 13/41). Those respondents who indicated an extremely negative impact were asked, how has switching to online instruction been difficult. In response to this question, 33.3% (2/6) of respondents selected lack of privacy or space needed for focus.

Most respondents indicated that online instruction impacted their laboratory classes in an extremely negative way (51.2%, 21/41). When asked why they believed that the quality of their instruction was reduced, 37.5% (3/8) indicated that it was due to the removal of hands-on learning experiences. Respondents' degree of liking online instruction was negatively correlated with lack of field experiences ($r(41) = -0.34$, $p < 0.05$), such that as participants liked online instruction less, there was a greater perception of lack of field experiences.

Mental Health Status

Regarding mental health status as assessed by the DASS-21, 16.6% (7/42) of respondents experienced depression, 7.1% (3/42) anxiety, and/or 9.5% (4/42) stress at the severe or extremely severe level. Additionally, 14.3% (6 of 42) of respondents reported moderate depression, anxiety,

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and/or stress. Overall respondents, the average depression score was in the mild range (M = 5.2, SD = 4.5) while levels of anxiety (M = 3.5, SD = 3.6) and stress (M = 5.4, SD = 4.4) were normal.

Discussion

In general, the STEM students who participated in this study maintained a relatively upbeat career outlook despite being in the middle of a global pandemic and experiencing major disruptions to their lives on many levels (e.g., change from residence hall to home, in-person to online instruction, social interaction restrictions). Respondents, who were mostly destined for biological/life scientist or natural resource careers, believed that attaining their career goals would allow them satisfying and exciting work, which would make a difference in people's lives. Participants were highly confident that they would attain their career goals, even with the current health concerns (COVID-19).

Knowledge about career, natural inclination, science related classes, parents and college teachers were identified as very important factors in supporting respondents' career path. This is in keeping with other research that also found that peers and family were rated as most important support for careers by college students (Peña et al., 2016; Raque et al., 2013).

Regarding reactions to COVID-19, most participants perceived that COVID-19 did not impact their career goals and were only moderately worried about the impact of COVID-19 on their future career. Moreover, many participants were optimistic that, if they were to continue on in their natural science career, they would be able to maintain good health. A strong belief in being able to maintain good health was associated with increased confidence in attainment of the individual's career goal. It is possible that the type of occupation of respondents (i.e., scientific and natural resources) in this study served to buoy the potential ill effects of the current situation and students preparing for very different occupations (e.g., occupational therapist, nurse) may be less optimistic.

From the perspective of SCCT, contextual factors such as the respondents' support system (e.g., parents, teachers) may provide insulation from barriers such as COVID-19 and unemployment rates resulting in confidence in career attainment (Lent, 2013). The results of previous research suggest that parents are perceived as having a beneficial impact on college students' career decision-making (Craig et al., 2018; Workman, 2015) and may even decrease career barriers (Raque et al., 2013)

In contrast to these relatively positive attitudes, the switch to online instruction was viewed unfavorably by most respondents. Similarly, in Baloran's study (2020), many of the 530 students surveyed from two private colleges in the Philippines also perceived as negative the change to online instruction due to the pandemic. In Baloran's study this negative perception of online instruction was primarily due to slow internet connections. In contrast, in the current study

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remote learning was thought by respondents to have an extremely negative impact on their laboratory classes and somewhat negative impact on their science classes. Respondents reported that the problems with online instruction were due to removal of hands-on learning experiences, field laboratory experiences, and/or direct peer/student interchange. From a SCCT model, a student's self-efficacy may be lessened when exposure to key laboratory experiences are lacking (Lent, 2013). Future research should target STEM students' career self-efficacy and how COVID-19 may impact it as it relates to the changes in the model of instructional delivery. A measure of self-efficacy was not included in this study.

It is possible that respondents' difficulties with online remote instruction (e.g., lack of hands-on learning, field experiences) will be mitigated in future by most schools. In addition to having more time for instructors to prepare for classes, albeit in person, online, or some combination of the two, institutions have ramped up their faculty development training and promoted new instructional tools (e.g., virtual labs, simulation labs, lab in a box that is mailed to the student) to tailor instruction to the content, learning objectives, and mode of delivery.

Although many students prefer in-person, hands-on instruction over online instruction, acquisition of course knowledge during remote delivery may be equal or even superior to that of in-class presentation of the material. Brinson (2015) compared virtual remote to traditional hands-on labs for learning objectives achievement (e.g., inquiry, practical skills) and found that it was the same or better for non-traditional labs in the 56 studies reviewed. Academic performance was not examined in the current study but should be explored in future research.

A major perceived barrier for achieving respondents' career goals was education costs. This barrier may have been an issue for students even prior to the epidemic. Finances were similarly perceived as the most significant barrier by the STEM students in Pena et al.'s (2016) study. The rising costs of tuition has characterized higher education in the U.S. (https://nces.ed.gov/programs/digest/d18/tables/dt18_330.20.asp). Although we did not assess this, an economic barrier may impact the likelihood that STEM students pursue their career path. Future research should evaluate if students who are supported with tuition grants are more likely to complete their degrees and continue in STEM fields compared to those without such support. Given the tremendous upheavals students were experiencing March through May, 2020 due to the COVID-19 pandemic, the occurrence of psychological distress is to be expected. Although a substantial number of respondents in the current study reported severe mental distress (19%), it was less than that found in other studies surveying college students during COVID-19 (Baloran, 2020; Rudenstine et al., 2020; Wang et al., 2020). Moreover, the incidence of mental health difficulties experienced by participants in this study were comparable to levels observed in other samples of college students pre-COVID-19 (Auerbach et al., 2016). In the current study, respondents' confidence in attainment of career goal was negatively associated with levels of anxiety. Other research has shown a relationship between student career self-efficacy and anxiety

(Işik, 2012). These findings suggest that providing support to promote students' career development may alleviate their anxiety.

Limitations of this study include small sample size and lack of diversity of the sample characteristics, which may reduce the generalizability of the findings. Additionally, respondents were from a small private college located in a rural setting, which may not be representative of students at larger institutions or those in an urban setting. The psychometric qualities of the COVID-19 questions also need to be better established with reliability and validity analyses.
Future research should evaluate whether students' career goals change across time as the pandemic unfolds. It may be that this assessment of students' views soon after the emergence of COVID-19 are unique and respondents' perspectives would differ if measured at other times. Other research questions to explore include whether STEM and non-STEM students share similar views. Possibly, the scientific quest to understand and solve the COVID-19 pandemic may be more intriguing to STEM students and these students experience less anxiety and more confidence about the future compared to non-STEM students.

Based on these survey results, possible actions to support STEM students achieving their career goals include:

- Identify approaches to online science instruction that incorporate hands-on or experiential learning (Beier et al., 2019; Mohammadi et al., 2019).
- Adopt empirically-validated, authentic instruction such as engaging and interactive online lectures and remote labs (Beier et al., 2019; Sauter et al., 2013).
- Provide information on college tuition funding sources and money management instruction to address financial barriers such as requiring students to complete a financial literacy course (Goetz et al., 2011)
- Address students' career-related anxiety by offering various career development opportunities (e.g., internship, service learning, conferences). Opportunities for students to engage in career exploration and work toward career goals may be fruitful in reducing career anxiety (Deer et al., 2018; Lent et al., 2019; Slovacek et al., 2019).
- Enlist parents and peers as effective support agents to encourage students' career development (Rozek et al., 2017).

The adjustment to the "new normal" will require flexibility, creativity and patience on the part of all involved in higher education. The academic classroom can now exist anywhere that communication between instructors and students is established. It will be critical to ensure that students and, in particular, STEM students who require interactive and experiential learning, have the ability to learn and absorb material through multiple methods (Education & Human Resources, 2020). Instructors' adaptability and feedback on instructional effectiveness is important pedagogy as we continue to acclimate to the COVID-19 academic challenges.

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