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Pathways to Science Careers: Exploring Perceptions of Science Educators and Professionals on Being a Scientist

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ABSTRACT

One function of modern education has been to prepare students for future college and/or career pathways. Particular attention in the US is given to preparation in STEM career fields. However, we may not be effective in advising students towards some STEM careers. This qualitative interview study evaluates the perspectives of stakeholders in science career preparation, including high school teachers and counselors, community college and university faculty, and science industry professionals. Interviews were conducted to explore participant perceptions on skills and dispositions students need to be successful in science careers. Results presented focus on areas of agreement and areas of difference between the stakeholder groups, and specific recommendations for practical change in science career development are discussed.

Keywords: science education, student skills and dispositions, qualitative interview study

Introduction

It has been argued that one purpose of education is to prepare students for their future college and/or career plans. Particular attention in education research has been given to *college and career readiness*, where students leaving high school should be prepared to enter college and/or the workforce without needing further developmental training (U.S. Department of Education, n.d.a). Additionally, the areas of science, technology, engineering, and mathematics (STEM) continue to receive particular attention due to projected advances in these career fields and the belief that STEM advances are important for the protection and development of the country as a whole (U.S. Department of Education, n.d.b). However, science careers continue to be pursued and staffed by primarily white males from middle to high social status families (Byars-Winston, 2014; Tyson et al., 2007). Underrepresentation by women, minoritized groups, and students with lower socio-economic status has been studied and addressed for years with little improvement (Falco, 2017; Swafford & Anderson, 2020). Additionally, we may not be as effective in advising students towards STEM careers outside of the most common science areas such as biology, engineering, chemistry, and physics (Byars-Winston, 2014; Falco, 2017; Rottinghaus et al., 2018). At a foundational level, one piece of this problem may be a disconnect between what our education system prepares students for in science, how we advise students around science careers, and what scientists need to be effective in their careers.

Theoretical Framework

While this is an exploratory study, a theoretical foundation is used to provide understanding. Social cognitive career theory (SCCT) provides a foundation of understanding for the career development process (Lent et al., 1994; 2002). SCCT provides a complex theory of career development for the individual where learning experiences impact self-efficacy and outcome expectations, which subsequently impact career interests, goals, and choices. Self-efficacy is the belief in one's ability to complete tasks toward a goal, and outcome expectations focus on the perceived outcomes, positive or negative, one connects with a specific career path. Career interests are the likes, dislikes, and indifferences an individual has about occupation activities and are key determinants in choosing a career (Lent et al., 2002).

SCCT also particularly highlights the role of person inputs, background affordances, and proximal supports and barriers in the overall career choice process, resulting in a more comprehensive framework for understanding career development. Person inputs in SCCT refer to components of the self that impact the career process, elements of identity such as age, gender, disability status, etc. (Lent et al., 1994, 2002). Background affordances such as family history, culture, ethnicity, and socio-economic status are also understood to impact career decisions and outcomes. Finally, SCCT breaks proximal contextual influences into two components: barriers to career decisions such as social stereotypes, or a lack of job opportunities, and supports to career decisions such as mentoring networks and internship opportunities (Lent et al., 2002).

Specific to STEM careers, Byars-Winston (2014) argues the need for a Multicultural STEM Career Development framework, specifically highlighting the ongoing barriers for students in minoritized and traditionally underrepresented identities accessing STEM opportunities and careers. Research has consistently shown the impact of lack of opportunity, decreased self-efficacy in STEM related content and courses, and lack of support as barriers for these students, regardless of actual ability (Byars-Winston, 2014; Rottinghaus et al., 2018; Tyson et al., 2007). Connecting this argument back to SCCT, Falco (2017) presents a synthesis of STEM career development research within the SCCT framework, and also highlights the need Byars-Winston (2014) had previously presented for targeted interventions with historically underrepresented groups. We therefore extend this argument with empirical evidence from across the STEM career development pathway, building on the foundation of SCCT and the extensions by Byars-Winston (2014) and Falco (2017) on the need to better understand the decision-making process and needed supports for students potentially pursuing STEM careers.

For the present study, educational experiences are addressed through the interviews of high school and college/university science faculty, and proximal supports and barriers are addressed through discussions with high school administrators in addition to science educators. Finally, the science professionals represent the culminating example of an individual who chose a science career, so theoretically they can be seen as an example of the successful completion of science career development. Understanding their experiences may help us better understand areas for change throughout the career development process.

Literature Review

Previous work has examined student perceptions of science and scientists at different levels of education (Farland-Smith, 2009; Finson, 2002; Fralick et al., 2009; Schibeci, 2006; Shin et al., 2015) and science educator perceptions (Akerson et al., 2012; Milford & Tippett, 2013; Ucar, 2012). Marked increase in such studies is noted since 1957, when researchers began examining students' impressions of scientists - the majority substantiating previous findings that students' representations of scientists are based on stereotypes (Finson, 2002; Farland-Smith, 2009; Schibeci, 2006). Many of these studies employed drawings (i.e., Draw-A-Scientist Test and related measures) and interviews as data generating methods (Milford & Tippett, 2013; Schibeci, 2006; Shin et al., 2015; Ucar, 2012). This data was used to evaluate pre- and post-perceptions about science dispositions, scientists, applicability, and ambitions.

Student Perceptions of Science and Scientists

While the present study is not focused on student perceptions, the distal outcome of the STEM career pathway is student interest and choices about STEM careers. Therefore, a discussion of the stakeholders and direction of the STEM career pathway must include a discussion on the issues we are seeing at the end of the pathway, namely the perceptions of students about these careers. Meta-summaries and analyses of multiple studies about students' drawings of scientists have been conducted to look at the collective patterns of beliefs about these careers (Ferguson & Lezotte, 2020; Finson, 2002; Miller et al., 2018). The common stereotypical impressions were scientists as glasses-wearing males of European descent with beards and mustaches, in a lab coat, and working in a room or chemistry lab (Ferguson & Lezotte, 2020; Finson, 2002; Fralick et al., 2009; Miller et al., 2018). There are multiple ways of interpretation and researchers have cautioned against taking students' visual representations as fact, as many drawings may portray whimsical or unrelated images, or may be impacted by the available materials and instructions given for the task (Ferguson & Lezotte, 2020; Finson, 2002).

However, these results support other findings that students' perceptions of scientists are associated with their own feelings about science, as well as perceptions about their own abilities, capabilities, and control (Finson, 2002; Fralick et al., 2009). For those with a stronger sense of self-perception in these areas, fewer aspects of stereotype were displayed in their drawings (Finson, 2002). On the other hand, scientists drawn by students of different races, gender, grade levels, and in different countries were all consistent in their stereotypical representations (Finson, 2002; Ucar, 2012). Self-efficacy has been consistently shown as the primary predictor of STEM career interest and choices (Aschbacher et al., 2012; Chemers et al., 2011).

Farland-Smith (2009) extended the work and findings of existing studies to specifically address the significance of culture as an influencer in the way students viewed scientists and their roles. From the position that schools are sites of cultural development, educational systems in schools across different nations provide the cultural factors that foster the formation of students' worldview. Therefore, their impressions of what scientists do is directly related to the predominant culture of the classroom and this includes the way in which science is taught (Farland-Smith, 2009; Finson, 2002). The societal influences of their cultural mores, including that of their school rooms, impacted learning and perceptions (Farland-Smith, 2009). A recurring implication of the literature on this topic is that the less stereotypical the image one holds, the more probable it is that one will opt to take more science classes and subsequently consider entering a profession in the sciences (Farland-Smith, 2009; Finson, 2002; Ucar, 2012).

Teacher Perceptions of Science and Scientists

Research on student perceptions of science and scientists continue to emphasize the importance of foundational experiences and exposure through education, explaining that positive perceptions of science can begin in elementary school (Farland-Smith, 2009; Shin et al., 2015). Science teachers need to be cognizant of the fact that many of their students have stereotypical impressions of scientists (Finson, 2002), and examine their own perceptions, as the way teachers teach influences the way students learn, and how they view science and scientists (Anderson, 2015; Mansour, 2009). Previous studies have supported that classrooms are a chief site for engagements with science, and teachers are critical authorities in students' conceptions of science (Anderson, 2015; Mansour, 2009; Milford & Tippett, 2013).

However, studies have illustrated pre-service teachers believe their own traditions, values, and beliefs are not the same as those of scientists, and this can impact how teachers provide science instruction (Akerson et al., 2012; Farland-Smith, 2009). Studies evaluating drawings by preservice teachers mostly demonstrated that they held stereotypical views of a male scientist with unkempt hair and glasses, wearing a lab coat in a lab (Finson, 2002; Fralick et al., 2009; Milford & Tippett, 2013). Teachers' perceptions and dispositions about science directly impact the content and instructional delivery of science, and the teacher preparation programs are a catalyst in the conception and reinforcement of these perceptions (Milford & Tippett, 2013; Ucar, 2012).

Changing Perceptions of Science

Finson (2002) suggested more research utilizing interventions to alter stereotypes to determine what the impacts were, rather than doing research focused only on the consistency of stereotypes. The researcher called for an examination of underlying assumptions and root causes behind stereotypical perceptions of scientists, moving past studies that basically confirm that students have stereotypical perceptions, and rather describe how interventions have impacted them (Finson, 2002). Both Finson (2002) and Schibeci (2006) suggested that stereotypical representations should not always be viewed negatively, because they do also encompass positive elements associated with scientists, and which may be necessary for identification purposes. But Schibeci (2006) also points to researchers who assert that in order for students to gravitate more to studying the sciences and select scientific careers, stereotypes are harmful.

Research has supported the impact of critical education interventions on students' views of scientists (Fralick et al., 2009; Schibeci, 2006; Shin et al., 2015; Zuo et al., 2019). Specifically, studies have highlighted the benefits of giving students opportunities to engage with working scientists as especially useful in cultivating practical impressions about scientists and the jobs they do (Fralick et al., 2009; Shin et al., 2015). Exposing students purposefully to not only realistic and practical science curricula, but also meaningful and realistic interactions with scientists can help prevent and change stereotypes (Schibeci, 2006; Shin et al., 2015).

University and college science professors could impact teacher candidates and those already teaching in differentiating between negative and positive elements in stereotypical images of scientists and effective ways of changing them (Finson, 2002). Changing the views of pre-service teachers so they see themselves as having similar traditions, values, and beliefs as scientists could positively influence the way they think about and teach science (Akerson et al., 2012). Future teachers should be exposed to courses that will build their self-efficacy as capable teachers of active and applied science, allowing them to be more successful and effective in communicating this to the diverse students with which they engage (Milford & Tippett, 2013).

Present Study

The purpose of this study is to gain a better understanding of the perceptions of science for key stakeholders along the science career pathway, looking specifically at places where there is perceived disagreement. While substantial research has been conducted on student and teacher perspectives of science and scientists, less work has been done in the research literature to understand school counselors' perspectives of science and scientists (Ferguson et al., 2019; Hall et al., 2011; Moore, 2006; Schmidt et al., 2012), and little was found focused on the perspectives of faculty members in college and university programs on scientists and science careers outside of academia (Knezek et al., 2011). The perspectives of scientists themselves are also rarely studied, possibly due to the broad nature of science careers and the difficulty in recruiting participants for research of this type (Makarem & Wang, 2020; Yore et al., 2006). Furthermore, no prior study was located that compares and contrasts the beliefs and perceptions of all stakeholders along the science career pathway, missing the opportunity to view this issue from the perspective of the career development process. Therefore, in the present study, data was collected from high school teachers, counselors, and administrators, from local community college and university faculty in science areas, and from industry professionals working in various science fields in the region. This exploratory qualitative study is guided broadly by SCCT (Lent et al., 1994; 2002) as a theoretical framework, and seeks to understand what these stakeholders believe about the skills and dispositions students need if they seek to pursue a science career. There are two specific research questions guiding the inquiry process in this study:

1. What are the perspectives of stakeholders along the science career pathway on what skills and dispositions students need if they want to pursue a career in science?
2. What differences, if any, exist between these stakeholders on these components of science and science career understanding?

Methods

The present study is an exploratory qualitative interview study focused on understanding the perceptions of the stakeholders along the science career pathway. The context of this study is localized to one state in the Northeastern United States to gain a focused view of the science career pathway for students in one state. This allows for a discussion of the interconnections between the educational entities but may also limit the application of these findings to this region. An early portion of this manuscript was presented at the American Education Research Association conference as a poster (Ferguson & Givens, 2020).

Participants

After IRB approval was gained, participants were recruited from local high school science and math teachers, high school counselors, high school principals and/or vice-principals, community college faculty, university faculty, and science professionals working in the region. A target of four participants per category (total $n = 24$) was set to allow for maximum variation sampling (Johnson & Christensen, 2018), looking for participants within each category that represent a different perspective or aspect of the science career pathway within their role. For instance, when recruiting high school teachers, school counselors, and principals, attention was given to recruiting participants from a variety of high school sizes, locations (urban, suburban, rural), and levels of experience. This is a useful approach to recruitment with a study that attempts to understand a broad perspective on a specific issue (Johnson & Christensen, 2018).

Data Collection

Participants were interviewed in one, one-hour session each by the primary researcher, at a location convenient for the participant. The interviews were semi-structured around three key questions: (a) *What do you believe science is, if you had to define it or describe the nature of it?*, (b) *In your opinion, what is a scientist? What does it mean to be a scientist?*, and (c) *In your opinion and based on your experience, what skills and/or dispositions do students need to be successful in science careers?* Follow up and probing questions were asked throughout to capture the experiences and perceptions of each participant as it relates to the focus of this study, including their perspective on the education and career development pathway for students in science related fields. All interviews were conducted by the primary researcher on this project. Additionally, participants and other educators were invited to a follow up discussion group to review the major study findings and discuss further. This served as a form of member checking and expansion of the data collected. These conversations are also considered in the data analyzed for this study.

Data Analysis

All interviews were recorded and transcribed verbatim by a professional transcriptionist. Both researchers coded the interview transcripts following a thematic analysis procedure as detailed by Braun and Clarke (2006). First, researchers independently coded participant responses to identify meaningful concepts in initial codes. Then, the team met to compare the resulting codes and refine or clarify codes collaboratively, discussing any discrepancies and creating a shared coding structure through consensus. Next, the participants' responses were evaluated again with the new coding structure, and each researcher identified broad themes across the codes in connection with the study research questions. Specifically, for this study, themes were identified within the study participant groups individually to facilitate cross-group comparison. Then, the themes from each participant group were compared against other participant groups to look for similarities and differences in beliefs and perceptions. Next, the researchers met to finalize the identified themes within and between groups, and any areas of disagreement were resolved collaboratively to reach consensus. Finally, the preliminary findings from the study analysis were disseminated back to the participants and other community stakeholders that did not participate in the original interviews through a workshop discussion group. A total of 10 professionals attended the follow-up session in the spring where the researchers shared the results of the study, and the group collectively discussed implications for students and educators and recommend practical changes. These discussions also informed the results reported here.

Results

A total of 24 participants were interviewed for the present study. The goal of four participants from each of the six role categories was almost fulfilled, except that there were only three participants for the community college faculty category and five participants for the high school administrator category. Descriptive information for the participants can be found in Table 1. The outcomes from this study focus on what students need to be successful in science, from the viewpoint of a cross-section of stakeholders in the science career pathway. Findings are organized first around what was found to be common between the different stakeholders along the pathway in relation to the three research questions. See Figure 1 for this information. Then, key differences in responses between the stakeholder groups are presented and supported, as shown in Figure 2.

Figure 1

Shared Themes From Key Study Variables

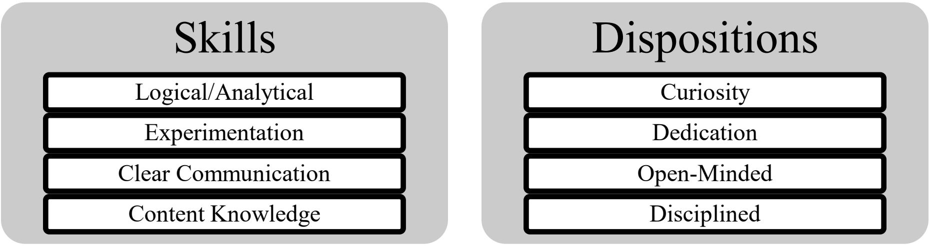

Figure 2

Notable Differences Between Stakeholder Groups on Key Study Variables

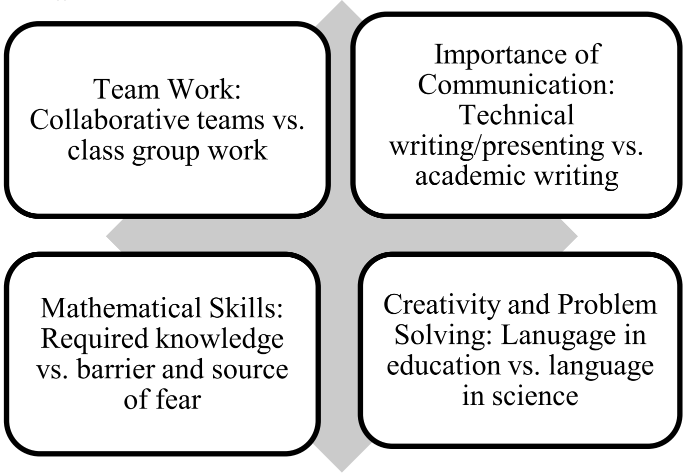

Table 1

Descriptive Information About Interview Participants

Role	Professional Title	Gender	Experience	Science Focus
High School Administrator	Assistant Principal, Supervisor	Female	2 years	
	Assistant Principal	Female	9 years	
	Principal	Male	1.5 years	
	Principal	Male	5 years	
	Principal	Male	18 years	
High School Counselor	School Counselor	Male	8 years	
	Guidance Counselor	Female	8 years	
	Director of Student Personnel Services	Female	10 years	
	Guidance Counselor	Female	22 years	
High School Science Teacher	Teacher	Male	1 year	Physics, Forensics
	Teacher, Science Club Advisor	Male	11 years	Biology
	Supervisor	Female	13.5 years	STEM, Instructional Tech
	Teacher, Science Club Advisor	Male	35 years	Physics
Community College Science Faculty	Dean, Professor	Male	11 years	Biology, STEM Division
	Assistant Professor	Male	16 years	Physical & Earth Science
	Professor	Male	28 years	Engineering
University Science Faculty	Associate Professor	Female	7 years	Physics
	Associate Professor	Female	18 years	Biology
	Professor	Male	10 years	Chemistry
	Professor, Director	Male	23.5 years	Ecology, Biology
Scientist / Industry Professional	Chemist	Female	7.5 years	Chemistry
	Lubricant Formulator	Female	15 years	Chemical Engineering
	Chemist	Male	8 years	Chemistry
	Pharmacist	Male	20 years	Pharmacy

Shared Perspectives

Participants had shared perspectives themed as four skills and two broad dispositions for students interested in science as a field. Areas of agreement were found in students' needing scientific skills such as logical and analytical methods, an understanding of experimentation as a method, the ability to communicate clearly, and foundational content knowledge. A principal with 18 years of experience suggested requisite skills to be a scientist would include "…reading, writing for sure, problem solving, critical thinking, being able to do an analysis of something, comparing and contrasting…and sort of problem solving." Math or analytical skills were mentioned repeatedly, but not always consistently as explained further in the next section. Communication, both written and spoken, was also discussed consistently, as one university professor noted:

> I think one that is underrated at least for students coming in is the communication skills. The verbal communication and the written communication is absolutely critical to be a successful scientist…Students need to be quantitative but they have to be able to communicate.

Content knowledge was also presented as a foundational need, but likely not the most important component of effective science preparation. A high school principal expounded on this idea, saying:

> If you're going to have that kind of understanding…that's going to lead to the next breakthrough, you need to understand what the rules are for those things and how those things interact…you do need to have a fundamental understanding of that content to keep progressing.

On the topic of dispositions, stakeholders generally agreed that students in science should be curious/open-minded and dedicated/disciplined. A university chemistry professor noted that students "…need to be able to learn, take in, and master new techniques…This is a constantly evolving and developing world…so they can't just go into industry with a knowledge set and expect that to carry them for 30 years." The importance of dedication and openness to failure in the process was repeated regularly. As one assistant principal said, it is important to help students see failure as an opportunity to learn, "And that's kind of like our mantra, that we don't want you to fail per se, but understand that without taking risks you're not going to grow." A high school counselor participant shared an anecdote from her school that highlights the role of failure and dedication in science clearly:

> I remember the one girl in this advanced topic biology class that Dr. A taught, she was doing something with mosquitos…and her mosquitos kept dying in her project, so she had to keep starting over. Then he was like, 'Alright well why do your mosquitos keep dying? What's going on?' And then she found out it was the temperature in the lab room, so we had to move her lab room. But she was getting so frustrated, and he's like, 'This is research. This is what happens…' And I think perseverance is one of the big things that is important.

Group Differences

There were also four notable differences in the themes of stakeholder beliefs about what students need to be successful in science careers: (a) importance of communication, (b) mathematical skills and knowledge, (c) understandings of creativity and problem solving, and (d) experience of teamwork.

Communication

First, the importance of communication was discussed throughout the participant groups, and a need for clear communication skills was noted as a shared theme. However, science professionals noted that the communication they typically engage in is in the form of marketing presentations for clients or company administrators, or brief communications and presentations to share results across teams. One scientist in chemical engineering expounded on the role of communication and technical writing in her work, commenting that receiving long emails with blocks of text was perceived as a waste of her time, but "if you have, you know, three or four headers with two or three bullet points each, then I'm definitely going to invest a few minutes to try and understand what you are telling me." More formal writing does happen in science professions as well, but this scientist noted that, "In 15 years, [I] have written five or six things that I might call an actual report, where I use page numbers and citations and references."

The communication taught and emphasized in educational settings may not always align with this need, suggesting additions may be needed in the science curriculum. A university professor in biology noted that in her high school experience:

> Those skills weren't as emphasized for scientists. If you wanted to major in English, you need to be good at writing. But if you want to be a scientist, you just need to be good in math. And I think that's a disservice.

A community college professor also noted the importance of communication in both technical and non-technical forms, arguing "And it comes down to not only reading and writing technical scientific papers, but it also comes down to just simple communication…how to convey that scientific information whether it's to a peer or whether it's to somebody that's a non-scientist." While verbal and written communication are foundational content areas in K-12 and higher education, we may not be effectively preparing students for the types of technical writing and presentations most common in the industrial and academic space.

Mathematics

Second, the role of mathematical skills and knowledge in science careers was highlighted throughout the interviews, and the analytical process of problem solving was noted as a shared theme. However, the differing perspectives on the importance of mathematical knowledge present a complex picture. On one side, mathematical knowledge is important for both linear and analytic thinking processes, and for the ability to use data to investigate and solve problems. However, math also appears to serve as a barrier for students interested in science, potentially a false barrier derived from fear or low self-efficacy towards math, instead of a true lack of ability to use math in applied contexts. One scientist working as a pharmacist noted that math does not play a major role in all science careers, noting that,

> If you can do basic algebra, basic calculus, I would even say differentiation. If you have that skillset, that is sufficient. You don't need to be able to write your own equations to solve a pharmaceutical problem. Is it beneficial? People majored in undergrad math, of course it's beneficial. Is it necessary? No.

Differences in mathematical skill requirements by fields of science were also noted a few times, as one high school counselor reflected, "There is a difference between…physics, that's a lot of calculus. Environmental science is a lot of statistics, and so *that* math is actually wildly different." The community college Dean participant noted essentially the same pattern, saying, "Chemistry…you know you've got to have that strong math background. Go into biology…you're going to use some statistics." However, he then went on to argue for advanced math preparation for all science students, saying,

> Everybody in science should get up through at least Calculus I if not Calculus II. And not necessarily because they'll use it, but specifically because it's going to open your mind to how you're going to manipulate and solve this math problem.

There is a noted lack of consensus in belief about the role and application of mathematical knowledge and skills in science careers, and one that cannot be resolved in the scope of this work. But consideration should be given to what level of mathematics training is really needed for students pursuing these different types of science careers.

Creativity and Problem-Solving

The third key concept noted by participants related to skills and dispositions needed for science was the idea of creativity and imagination. Multiple educators in the study mentioned this as a key disposition for science careers, but no scientists mentioned the concept of creativity specifically in their discussions. For educators, the idea of creativity is an important one throughout the interviews, as one biology professor making the claim that students "…might be very good at organizing their thoughts and all that, but without that creative drive, they're not going to become research scientists." This term not being used in the interviews with the scientist participants was noted in early analysis by the research team. However, further discourse during the discussion group held following the interviews highlighted a possible difference in language. Specifically, it was discussed that scientists may not use the term "creativity" to discuss their work, and instead refer to this skill as "problem solving" or identifying unique solutions.

A second look at the interviews of the four scientist participants revealed mention of solving problems, like the chemical engineer noting, "Being a scientist and solving problems, you're going to be coming up with ideas." Though her focus was largely on issues of compliance and marketability, she explained,

> If I have a product, I need to create that product in a way that complies with all local, state, federal, and global regulations…I will need to document the way that it complies, and I will have to sometimes manage and steward a budget in which I am applying for those confirmation…It has to be accurate. I need to think about all the people who need to know what my product is about so that they can sell it, market it, commercialize it, manufacture it, package it, and label it.

While not traditionally how educators might think of creativity, this kind of critical thinking and development is key to her work as a scientist. Other scientists noted similar thoughts, with the male chemist noting the importance of:

> …curiosity, analytical skills, being able to look at data and draw conclusions, being able to parse out from the data what really is important and what is just chaff, and being able to think a problem through, think of possible solutions and how you're going to get to those solutions.

Additionally, the female chemist participant noted the limitations of education in developing this kind of thinking, saying, "Sometimes we get recent grads with their B.S. in Chemistry, and they're not prepared. They have just gone through the motions. They haven't been taught all the soft skills that they need." This finding is multifaceted, as creativity is an area of focus in education that we may not be effectively supporting for those seeking science careers. But this is also a potential example of the need for clarity around language and meaning. This is so that stakeholders in education contexts are clear on what they mean by concepts like creativity, and design their programs to build on important elements of this skill related to problem solving and application.

Teamwork and Collaboration

Finally, the concept of teamwork came up as a key concept for science professionals and educators. Across the stakeholder groups, collaboration and teamwork was noted as an important skill in science. However, science professionals highlighted that the type of collaboration they engage in is more individual responsibility with results shared across team members who are working on other components. As one scientist in chemical engineering explained,

> Part of being on a team is learning about people on your team. There are going to be people who will not speak unless you ask them a question, and that doesn't mean that their ideas are any less valuable…But there are going to be other people who are more forceful and who will trample on your idea, so you have to be able to engage them as well...

The scientist participants consistently highlighted the importance of interpersonal skills, finding balance in collaboration between ideas for different members of the group, and working independently on tasks and then sharing results with the group. However, collaboration or teamwork in education contexts is often very different, with more direct group work and shared responsibility for the same tasks, like a group project in a course. A couple of the scientists directly addressed this perceived misalignment between education and science as a profession. Here, one chemist shares her experience with teachers of her own children:

> I've heard some of my son's teachers, 'Oh yeah, we're doing group work!' That's really great, but that's not balanced… I'm thinking in the back of my mind, 'It's like you have no clue of how real life actually works, because yes group work is important, but I do the majority of my work by myself.' That's how we all are. We do have group sessions, but the majority of the time we're working on our own laptop on our own deliverables.

This appears to be an area where educational stakeholders may not be using collaboration and group work in the same way as it is used in science. While we say we are doing these things in classrooms, it is not clear that we are really preparing students for professional expectations.

Discussion

The purpose of this study was to gain a better understanding of the perceptions of science for key stakeholders along the science career pathway, speaking with high school teachers, counselors, and administrators, from local community college and university faculty in science areas, and from industry professionals. Analysis focused on comparing and contrasting the beliefs and perceptions of these various stakeholders along the pathway to explore this issue from the perspective of science career as a developmental process (Lent, et al., 1994; 2002). The two research questions guiding this study were:

1. What are the perspectives of stakeholders along the science career pathway on what skills and dispositions students need if they want to pursue a career in science?
2. What differences, if any, exist between these stakeholders on these components of science and science career understanding?

Answering research question one, there was also a great deal of consistency in how stakeholders discussed skills and dispositions needed for success in science careers, including analytical methods, the ability to communicate clearly, foundational content knowledge, and an understanding of experimentation as a method. These findings are also generally in line with prior research, especially on the soft skills sometimes referred to as 21st century skills such as public speaking and problem solving (National Education Association, 2020; National Research Council, 2012), and science content standards emphasized in education through the Next Generation Science Standards (2013).

Research question two addressed differences between the stakeholder groups, and four key areas of inconsistency were noted: (a) the role and form of communication, (b) the need for mathematical skills, (c) creativity in science, and (d) group work and collaboration in education versus in careers.

Role and Form of Communication

Participants highlighted the role of communication in science careers, arguing both verbal and written communication play important roles in these professions. However, this appears to be an area where education and industry are not addressing these skills in the same way. We know the importance of written and verbal communication in science and other areas, and NGSS (n.d.) supports this specifically in relation to science content. However, results from this study suggest educators should continue to consider ways to increase technical writing beyond the traditional lab report format common in classrooms and look at ways to expand assignments to model more closely industry expectations (Elliott et al., 2016; Moon et al., 2018). This could be a key space to collaborate with industry, bringing in science professionals to classroom spaces to share their knowledge and experiences on cross-cutting topics like communication (Yore et al., 2006). Additionally, cross-disciplinary collaborations in schools between science and English writing teachers could be meaningful in addressing this perceived area of need in science education.

Need for Mathematical Skills

Participants in the study presented two opposing perspectives on mathematical knowledge requirements for science careers. On one side, participants supported the need for advanced mathematical skill and thinking to support students interested in science careers. Conversely, an alternative perspective was presented with math serving as a barrier for many students, and participants pointed out that in many science professions advanced calculus type mathematical skills are not necessary. Science career development and STEM education as a whole need to continue this discussion on the role of mathematical skills in science career development.

We know some science careers require higher levels of math to be effective (Schroeder et al., 2007; Young et al., 2018), but participants in the present study were clear this is not the case across all science careers. And we have extensive research on the barrier that mathematical knowledge and course performance has played in blocking students from science or STEM pursuits as a result of tracking in education (Ozer & Perc, 2020; Spade et al., 1997), advising against advanced course taking for women or students of color (Vijil et al., 2016), and limited opportunities for advanced course work in mathematics or science for students in urban and rural communities (Flowers & Banda, 2019; LeBeau et al., 2020). If students are interested in a science or STEM career that does not require advanced calculus, and we are barring these students from access to advanced coursework or opportunities because of a lack of this mathematical skill, we are directly contributing to the lack of participation in science and STEM we consistently see for women, students of color, students from rural communities, and those with other underrepresented identities. Further research is needed to clarify the requirement of advanced mathematical knowledge in specific science and STEM careers, with particular focus on helping students make the connections between mathematical knowledge and their career interests.

Creativity in Science

Participants in the present study also differ in their understanding of creativity and problem-solving in science careers. Creativity is a complex concept in education, with a consistent lack of agreement on how we should define creativity (Kaufman & Baer, 2012; Martin & Wilson, 2017) and how we can best support students in developing creativity (Glăveanu, 2018). While educators in the present study mentioned creativity repeatedly, scientists did not, though they did discuss problem-solving and finding solutions to practical problems in their comments.

Inconsistency in language on its own is arguably not a problem, but potential inconsistency in how we support and develop creative thinking and problem-solving is worth noting. Educators should consider how they are supporting creativity in science content courses and explore ways in which they can help students develop divergent thinking and unique solutions to problems (Hong & Song, 2020). Integrating science curriculum with the arts has recently regained attention (science technology engineering arts and math, STEAM), and consideration could be given on how to integrate creative and improvisation practices from the arts into science content, which could support student development of this kind of creative thought (Sousa & Pilecki, 2013; Wilson, 2018).

Group Work and Collaboration

Participants in the present study highlighted the perceived disconnect between how group work is often formulated in schools and how it is used in practical application in science professions. Scientists in the present study specifically highlighted their frustration with K-12 education group work and how it is not applicable to the "real world" of their profession. Research on science teaching supports the importance of group/collaborative work for learning (Freeman et al., 2014; Fung & Lui, 2016), but maybe we need to consider more authentic group experiences like team-based learning (Espey, 2017; Jeno et al., 2017) or project-based learning (Beier et al., 2018; Merritt et al., 2017) with clearly delineated group roles and responsibilities (Chang & Brickman, 2018). Educators should examine whether we are effectively teaching collaboration in the ways we currently organize and require group work.

Social Cognitive Career Theory

While this was an exploratory study, SCCT is used as a general framework to provide further understanding to the findings (Lent et al., 1994; 2002). For students to effectively develop interest and career goals in science fields, SCCT posits they must have learning experiences related to science that develop science career self-efficacy and positive outcome expectations. Additionally, students should receive positive proximal supports as they pursue their interest in science careers and have the ability to overcome barriers presented along the process.

The present study findings align with this theoretical conception of career development as participants highlighted the need for positive and varied learning experiences to develop self-efficacy in relation to skills and dispositions connected to science careers. They also discussed the potential barriers and supports that could be provided as students pursue these interests, another key element of SCCT career development. Byars-Winston (2014) and Falco (2017) have expanded on this particular element of career development and can be seen as an extension of SCCT with considerations for career development professionals in STEM specifically. The findings in the present study confirm prior research using SCCT to explore STEM career development (e.g. Fouad & Santana, 2017; Sasson, 2020), and future explorations of the science career development process may benefit from this theoretical perspective (Brown & Lent, 2019; Byars-Winston, 2014; Falco, 2017). Connections between study findings, theoretical considerations, and practical recommendations are presented in Table 2.

Table 2

Summarizing Study Findings, Connections to Theory, and Practical Recommendations

Key Study Findings	Practical Recommendations	Theoretical Connections
Role and Form of Communication	Integrate assignments to practice technical writing in science courses (memos, emails, etc.), and collaborate with industry partners to share their experiences with writing and speaking in their work	SCCT argues learning experiences impact self-efficacy about career skills, such as both communication and mathematics, and students need these experiences to develop interest in science careers
Need for Mathematical Skills	Be clear with students on the different roles math plays in different science careers; acknowledge student fears and the barriers to mathematical skills, and create opportunities for learning	SCCT, Byars-Winston (2014), and Falco (2017) all argue that individuals need support to overcome stigma and barriers, such as reinforced anxiety and the lack of access to advanced math
Creativity in Science	Develop assignments and experiences to build divergent thinking in science courses, and integrate arts activities such as improvisation and free drawing to practice these skills	SCCT presents that students must be able to see themselves in a career to develop career goals, and experiencing the types of problems real scientists work with can encourage this development
Group Work and Collaboration	Utilize authentic Team-Based Learning and/or Problem-Based Learning, with clearly defined group roles and responsibilities to model real-world collaboration	SCCT supports positive learning experiences as key to development of career interest, and teamwork is a key component of science careers students should experience

Conclusion

This project serves as a foundational exploration of the science career pathway in one northeastern state in the US to develop a deeper understanding of the perceptions and beliefs of stakeholders on how we can best support students interested in science as a career. The results of this study provide a foundation for future studies and interventions along the science career pathway to better support students. Targeted interventions supported by this work could be focused on helping educators improve collaboration and group projects in their classes to better model professional collaborations, increasing educational support for the types of communication used regularly in science careers, addressing the disagreement in the field on the role of mathematics in science career development, supporting different forms of creativity in the science classroom, and continuing to increase opportunities for science career exploration.

While this study is limited to a single state in one region of the US, the findings from the present study align with prior research on these issues, supporting the application of these results to a broader audience. The regional nature of the study and the small sample in each stakeholder category did impact representation of science areas, with a higher percentage of chemistry professionals in the study matching the industry type common in the region. Additionally, this study is uniquely positioned as a cross-sectional exploration along the career development pathway, with identified areas of agreement and areas of inconsistency that expand our understanding of science education and career development. If we posit education as a space for the development of skills and dispositions for future college and career pathways, then professionals along this pathway will benefit from time and space to evaluate their practice against these findings and explore ways to better support their students in their career development.

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