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‘I Actually Contributed to Their Research’: The influence of an abbreviated summer apprenticeship program in science and engineering for diverse high-school learners

Stephen R. Burgin[a], William J. McConnell[b] & Alonzo M. Flowers III[c]
[a] Department of STEM Education and Professional Studies, Old Dominion University, Norfolk, VA, USA
[b] Department of Teaching and Learning, Old Dominion University, Norfolk, VA, USA
[c] Department of Educational Leadership, Counseling, and Foundations, The University of New Orleans, New Orleans, LA, USA
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'I Actually Contributed to Their Research': The influence of an abbreviated summer apprenticeship program in science and engineering for diverse high-school learners

Stephen R. Burgin[a*], William J. McConnell[b] and Alonzo M. Flowers III[c]
[a]*Department of STEM Education and Professional Studies, Old Dominion University, Norfolk, VA, USA;* [b]*Department of Teaching and Learning, Old Dominion University, Norfolk, VA, USA;* [c]*Department of Educational Leadership, Counseling, and Foundations, The University of New Orleans, New Orleans, LA, USA*

This study describes an investigation of a research apprenticeship program that we developed for diverse high-school students often underrepresented in similar programs and in science, technology, engineering, and math (STEM) professions. Through the apprenticeship program, students spent 2 weeks in the summer engaged in biofuels-related research practices within working university chemistry and engineering laboratories. The experience was supplemented by discussions and activities intended to impact nature of science (NOS) and inquiry understandings and to allow for an exploration of STEM careers and issues of self-identity. Participants completed a NOS questionnaire before and after the experience, were interviewed multiple times, and were observed while working in the laboratories. Findings revealed that as a result of the program, participants (1) demonstrated positive changes in their understandings of certain NOS aspects many of which were informed by their laboratory experiences, (2) had an opportunity to explore and strengthen STEM-related future plans, and (3) examined their self-identities. A majority of participants also described a sense of belonging within the laboratory groups and believed that they were making significant contributions to the ongoing work of those laboratories even though their involvement was necessarily limited due to the short duration of the program. For students who were most influenced by the program, the belonging they felt was likely related to issues of identity and career aspirations.

*Corresponding author. Department of STEM Education and Professional Studies, Old Dominion University, Norfolk, VA 23529, USA. Email: sburgin@odu.edu

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Introduction

Currently in the USA, emphasis is being placed on the importance of scientific and technological innovation as attempts are made to solve global and national problems (Committee on Prospering in the Global Economy of the 21st Century, 2007). In order to solve these problems, a scientifically literate citizenry is needed and, in particular, skilled science, technology, engineering, and math (STEM) professionals are of the utmost importance. Complicating matters is the unfortunate reality of the underrepresentation of students from minority populations who are interested in and ultimately pursue future educational pathways that might result in their membership within the STEM professional community of practice (National Academies of Science, 2010). This underrepresentation of STEM professionals from diverse communities is problematic for a number of reasons. Hyde and Kling (2001) argue that the success of women in professional workplaces (a traditionally underrepresented group in STEM communities) is vital to the economic health of the USA. Others argue and evidence demonstrated that workplace productivity and group problem-solving creativity increases not only as a function of traditional aspects of diversity (e.g. race, gender, etc.), but also as a result of contributions made by people holding diverse perspectives (Goffee & Jones, 2013; McLeod, Lobel, & Cox, 1996). We strongly believe that scientific progress benefits from cultural diversity among research professionals as new questions and problems are posed and unique individuals suggest possible avenues for exploring and answering them. Much attention has been focused on undergraduate opportunities in STEM for underrepresented populations and how their interest in STEM develops (e.g. Hrabowski, 2003; Kokkelenberg & Sinha, 2010). In our view, in order to expand the STEM-related interests and aspirations among all learners, then our attention must be turned towards programs and opportunities that may have a positive impact on students even earlier than at the undergraduate level.

Underrepresented students' images of themselves may have something to do with their success in and commitment to science. Race and gender indeed have been demonstrated to be indicators that shape peoples' opportunities to pursue STEM-related futures and their self-identification within science (Carlone & Johnson, 2007; Carlone, Scott, & Lowder, 2014; Museus, Palmer, Davis, & Maramba, 2011). Walls (2012) examined young African-American children's images of scientists and understandings of science and found that they held on to some stereotypical views of professional scientists as being white males while at the same time viewing themselves as members within the scientific community (their science identities). Why then do older children tend to feel more disenfranchised when it comes to science than do younger children (Carlone et al., 2014)? Is it because the ways in which science as a disciplinary way of knowing is taught in traditional school settings (particularly at the secondary level) tend to not value the unique culture funds of knowledge held by diverse learners (Calabrese Barton, 1998; Calabrese Barton & Tan, 2009; Wright, 2011)?

Possible ways to leverage students' funds of knowledge include engaging them in meaningful, collaborative, and authentic scientific inquiry (Rivera Maulucci, Brown, Grey & Sullivan, 2014). Scientific inquiry typically takes place through laboratory investigations. In their literature review on the use of the science laboratory in school-based settings, Hofstein and Lunetta (2004) conclude that 'laboratory work is an important medium for enhancing attitudes, stimulating interest and enjoyment, and motivating students to learn science' (p. 34). They continue to say that engaging in laboratory investigations can be particularly empowering for underrepresented populations. However, if authenticity of laboratory work is defined by the similarities it shares with the work of STEM professionals (Roth, 1995), then school science investigations can often be classified as less than authentic for cognitive and epistemological reasons (Chinn & Malhotra, 2002). Out-of-school opportunities could allow for practical science experiences that are more authentic than those which take place in school (Braund & Reiss, 2006). In our view, research apprenticeships, where mentorship by STEM professionals takes place, offer one of the best venues for doing just this (Sadler, Burgin, McKinney, & Ponjuan, 2010). For reasons like these, we believe that it is important to develop both in-school and out-of-school learning opportunities for K-12 learners from all underrepresented demographics within STEM (e.g. students from racial and ethnic minorities, female students) to engage in the practices of professional scientists (possibly through laboratory investigations in professional contexts) in ways that may positively impact their science identities.

We would be remiss not to mention at this point one potential barrier to successful participation by pre-collegiate learners in professional STEM laboratories. This barrier is the likely disconnect between the lived real-world experiences in science both at home and at school by K-12 learners and the realities of a working and contributing professional STEM community in a highly authentic setting. Aikenhead (1996) discusses 'cultural border crossings' between science experienced in the real-life of learners and in school science. What results is a 'cognitive conflict' and subsequent 'collateral learning' as a student must resolve understandings of science from different domains (Aikenhead & Jegede, 1999). If a border must be crossed between science outside of school and science as experienced in traditional school settings, how much wider must that border be between those experiences and a professional laboratory environment? This is not unlike the distinction made by Sandoval (2005) between students' practical epistemologies of science situated in their own experiences in scientific inquiry and their formal epistemologies related to understandings of professional scientists. Buxton (2006) discusses different types of authenticity (canonical, youth-centered, and contextual) and ultimately argues for a contextual approach that serves to link students' lived experiences and interests with the canonical authenticity of the practices and types of problems facing professional scientists. It was our hope that by situating the apprenticeship under investigation here in the context of a real global problem (energy needs), our participants might have experienced a sort of contextual authenticity that may have served to help them successfully cross the border into their laboratory group.

In light of the above discussion, we developed and investigated a research apprenticeship program that specifically recruited high-school students likely to come from certain underrepresented populations within STEM professions to work with STEM professionals on biofuels research in an authentic context. Targeted aspects of our investigation included the impact of the program on nature of science (NOS) understandings, future STEM-related plans, and the self-identities of our participants. It was our belief that by embedding high-school students within working laboratory groups, they might experience an enculturation into those groups that might result in a sense of belonging within a community of practice related to the aforementioned outcomes.

Literature Review

Research Apprenticeships

Research Apprenticeships are potentially quite valuable experiences for students with an initial interest in STEM (Burgin, Sadler, & Koroly, 2012; Sadler et al., 2010). Unlike what often happens through traditional school curricula (Chinn & Malhotra, 2002), students in research apprenticeship programs are often given the opportunity to make meaningful contributions to scientific knowledge through engaging in activities that are closely similar if not identical to the practices occurring within a research laboratory or field-based setting. The work that learners engage in during these apprenticeships may involve participation in an ongoing project with an unknown answer to a problem with real significance to the STEM community and may therefore be thought of as being highly authentic (Burgin & Sadler, 2013b). These experiences typically take place in the summer in professionally authentic contexts (often on college campuses), with some programs lasting as long as 2 months (e.g. Bell, Blair, Crawford, & Lederman, 2003) and one aimed at middle school students lasting only 2 weeks (Hay & Barab, 2001). Mentorship may be provided by research faculty (Sadler et al., 2010) or by their graduate students (Bleicher, 1996). Some programs have specifically targeted female and minority participants (e.g. Wallace & Pederson, 2005). According to a recent review of the literature regarding empirical studies of research apprenticeship programs (Sadler et al., 2010), positive outcomes of participation in these sorts of experiences include the development of sophisticated NOS understandings of participants (e.g. Bell et al., 2003; Charney et al., 2007; Richmond & Kurth, 1999; Ritchie & Rigano, 1996), the fostering and refinement of student interest in possible STEM-related futures (e.g. Abraham, 2002; Burgin et al., 2012; Davis, 1999; Stake & Mares, 2001), increased confidence (e.g. Stake & Mares, 2001, 2005; Templin, Engemann, & Doran, 1999), scientific content knowledge gains (e.g. Abraham, 2002; Charney et al., 2007), and a variety of other desirable outcomes. Recent work has revealed potential positive impacts to the science identities of female learners who interacted with female scientists in a short (5-day) out-of-school summer program that although we would not classify as a research apprenticeship, did involve hands-on laboratory work (Farland-Smith, 2012). Additional research has examined the impact of undergraduate research programs on the identity and future aspirations of students from diverse backgrounds in addition to their understandings of the culture of science (Hurtado, Cabrera, Lin, Arellano, & Espinosa, 2009). Unfortunately, many research apprenticeships for high-school students charge the participant high tuition rates and therefore might not attract a particularly diverse population in terms of socioeconomic status and subsequent ethnicities (Burgin & Sadler, 2013a). In the sections that follow, we will focus on the aforementioned benefits of participation in research apprenticeship programs that most directly relate to the current study.

Nature of Science

NOS as an instructional outcome is an important component of the development of scientifically literate citizens and as such has been featured in reform documents in science education over the past few decades (American Association for the Advancement of Science, 1993; National Research Council, 1996, 2007, 2012). Most recently, the Next Generation Science Standards (NGSS) featured NOS as an important construct upon which to reflect as K-12 learners engage in the practices of science and engineering (NGSS Lead States, 2013). Our conceptualization of NOS draws most heavily from the perspectives of Lederman (1992, 2007). Lederman argues that NOS should be an explicit feature of science curricula and that learners ought to be intentionally engaged on opportunities to participate in activities and subsequent reflections that enable them to develop more informed conceptions of generally agreed upon NOS aspects. These aspects include the empirical NOS, the creative NOS, the subjective NOS, the socially and culturally embedded nature of scientific knowledge, the tentative NOS, the differences between theories and laws, and the idea that there is not any one single method by which scientists engage in their work (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). We also believe that inquiry-based science activities in which learners participate have the potential to be linked to explicit learning about NOS (Duschl & Grandy, 2013). However, as science education researchers, we are often asking students about their understandings of the epistemology of professional science when they themselves might not have personal experiences apart from potentially less-than-authentic school science (Sandoval, 2005).

Research apprenticeship programs allow learners to 'do' science in ways that we believe (with proper supported reflection and engagement in NOS activities) can be influential in how they impact learners' NOS conceptions. For example, Charney et al. (2007) reported that secondary student participants of a research apprenticeship program developed more informed perspectives of the tentative NOS. Richmond and Kurth (1999) and Ritchie and Rigano (1996) similarly found that students who were participating in a research apprenticeship developed an understanding of the uncertainty of scientific knowledge (Sadler et al., 2010). Bell et al. (2003) found less positive impacts to student NOS understandings in the context of an apprenticeship program that did not explicitly feature NOS. However, they did find some impact on NOS ideas for a participant who engaged in explicit reflection and epistemic demand that was supported by her mentor scientist as she engaged in complex and authentic research. Our own work points to the power of research apprenticeships to impact understandings of the creative NOS, the social-embeddedness of science and the myth of the scientific method among other things, particularly when participants are involved in the development of their research project (Burgin, Sadler, & Barko, 2013).

Future Aspirations

As was discussed in the introduction, there is a strong desire among various factions of our society to increase the numbers of students who choose STEM-related futures. Perhaps participation in research apprenticeship programs has a role to play in achieving such a goal (Sadler et al., 2010). Indeed, research indicates that participation in authentic out-of-school scientific research can increase students' (including those from underrepresented groups) interests related to pursuing science-related careers (Abraham, 2002; Davis, 1999). Stake and Mares (2001) and Burgin et al. (2012) document that students typically enter research apprenticeship programs with high interest in science and generally with a desire to pursue an STEM-related future, but that their experiences in an apprenticeship program can introduce them to a variety of career options that they have not yet considered or can help them to solidify or refine their desire to pursue some sort of science career. Others have documented the value of research experiences for undergraduate students in STEM and the role that these experiences play along with others in fostering graduate and career work in STEM fields (Kendricks & Arment, 2011).

Identity

Identity development has been a topic of research in a variety of disciplines within the social sciences including education (e.g. Bonner, 2010; Hrabowski, 2012). The process of identity formation is complex and is shaped by personal real-world experiences and social interactions as an individual constructs a perception of self (Abes, Jones, & McEwen, 2007; Erikson, 1968; Gee, 2000). These self-constructions of identity are then largely a product of membership within larger social groups (Taijfel, 1981). STEM communities represent one of these larger social groups within which identity formation may take place. Research into identity development for individuals from underrepresented groups in STEM (women and ethnic minorities) has pointed to the influence of factors such as achievement, motivation, attitudes toward school, self-awareness, and self-efficacy in shaping constructs of self (Brickhouse & Potter, 2001; Flowers, 2011; Hanson, 2004; Hrabowski, 2012). However, more research is needed in the area of identity development as related to

STEM education (Christidou, 2011). For example, questions remain regarding factors that influence the development of positive science identities and the role teachers may play in the process.

Science educators have suggested that participation in authentic practices of both science and engineering can support the continued development of STEM identities particularly for marginalized students (e.g. minority and/or female) (Rivera Maulucci et al., 2014; Roth & Tobin, 2007; Tan & Calabrese Barton, 2008). Additionally, there is evidence indicating that experiences where students have out-of-school encounters with diverse science professionals have the potential to alter students' notions of who is capable of participating within scientific communities (Farland-Smith, 2012). Richmond and Kurth (1999) similarly draw on notions related to the building of identity that accompanies enculturation within scientific communities of practice in their study of a diverse group of participants in a research apprenticeship program.

Confidence

When participating in authentic research apprenticeship programs in science, high-school students have been shown to develop an increased confidence in their abilities to contribute meaningfully to the research in which they are engaged (Stake & Mares, 2005; Templin et al., 1999). Large numbers of undergraduate participants of a research apprenticeship program also reported increased confidence and/or self-identification as scientists as a result of their experiences which involved meaningful contributions to scientific research (Hunter, Laursen, & Seymour, 2007; Seymour, Hunter, Laursen & Deantoni, 2004). The authors of these studies say that 'the results of increased confidence to do science are expressed in students' accounts that show both tacit and unconscious development of traits, behaviors, and attitudes that are part of their development as young scientists' (Hunter et al., 2007, p. 53). In other words, when students develop increased confidence in their abilities, they may develop more positive images of themselves as members within STEM communities, which in turn could have an impact on their career aspirations. Thus, future aspirations, identity and confidence are likely interrelated for participants of authentic research experiences in STEM.

Unanswered Questions

Our own research into the impact of apprenticeship programs combined with that of other research previously cited leaves us with many unanswered questions about the impact of these programs in general and for underrepresented students in particular. Chief among these are questions regarding the nature of the experience. How much time is needed? What sort of activities should students be involved in? Is merely being embedded in an authentic context enough, or do participants need to be truly and meaningfully participating in the research to see desirable impacts on outcomes such as career aspirations and science identity? Do participants need to have a degree of epistemic involvement in the development of the research project, or is participating in ongoing research sufficient? Would more authentic involvement potentially be related to more informed understandings of NOS? What if students are placed in laboratory contexts where their mentors do not share any of their demographic characteristics? Would participants still feel notions of belonging, and would that belonging result in positive outcomes? It was in response to these wonderings that this research study was developed and implemented.

Methodology

Theoretical Framework

Much like the previously mentioned research involving research apprenticeship programs (Sadler et al., 2010), this study was guided by a theoretical framework that was largely informed by situated learning theory and sociocultural perspectives on science education (Lave & Wenger, 1991; Lemke, 2001). According to situated learning theory, learning takes place as learners participate legitimately in the real practices of a community. In order to provide the most powerful opportunities for participants to learn, the environment needs to provide authentic contexts and tasks for students even when those tasks take place on the periphery. We acknowledge that this engagement in practical work is a human activity that takes place in a context with cultural norms of a community of practice. Our work was also very much framed by Aikenhead's (1996) notions of 'cultural border crossings'. In the setting under investigation here, students engaged in both the observation of and, to a certain extent, the authentic participation in research practices related to ongoing biofuels investigations. These investigations occurred within the sociocultural contexts of science and engineering laboratory groups. Because of the topic of investigation (biofuels research with real-world consequences regarding an issue of global significance), we believed that the relevant context of the work would assist learners in crossing cultural borders while developing positive views of themselves as contributors to meaningful research (Buxton, 2006). We also took the perspective that personal belonging/positioning within those laboratory groups would likely be related to investigated outcomes.

Research Questions

The following research questions were derived from the aforementioned issues.

(1) What influence did program participation have on (a) NOS and Inquiry understandings, (b) STEM-related plans, and (c) identity?
(2) What was the nature of the positioning (both by self and others) of the participants within the laboratory groups in which they had been placed?
(3) How did the feelings of students regarding their place within laboratory groups relate to the investigated outcomes of program participation (NOS and inquiry, STEM-related plans, identity)?

Participants

The recruiting of participants took place through an application process facilitated by the district-wide science coordinator of a large urban school district in the Mid-Atlantic USA. This district had a high minority population with large numbers of students from low socioeconomic backgrounds. As such we targeted it as a potential source of diverse participants. Through this process, we identified eight high-school participants who were rising juniors or seniors (one Black/African-American male, three Black/African-American females, four White Non-Hispanic females). The application prompted students to reply to a handful of essay questions, and submit their high-school transcripts and a letter of recommendation from a math or science teacher. Collectively, the population selected for enrollment in the program demonstrated a sufficiently strong background and interest in science, an initial interest in STEM-related futures, a burgeoning science identity, room for development in their understandings of NOS, and were from underrepresented groups (Table 1).

Program Overview

These students then participated in a 2-week summer research apprenticeship program that we developed to take place at a research university in a neighboring city. Before continuing we wish to briefly address the limited timeframe of our program. As we were developing a program from the bottom-up, we had limited funding to offer our program participants and we relied on the volunteer efforts of our mentor scientists and their graduate students. We also knew that our diverse participants would likely have summer plans in place that would necessitate a shorter program. Therefore, we made the decision (although an informed one) to run a 2-week program given the success of another similarly short program (Hay & Barab, 2001). In spite of the short duration of the program, it was our hope that the experience would provide the opportunity for likely diverse high-school students to work side-by-side and under the mentorship of professional scientists or engineers and their laboratory research groups (graduate students) on ongoing biofuels-related

Table 1. Participants

Name	Gender	Race/Ethnicity	Grade	Research group
1. Jacob	M	Black/African-American	Rising junior	Engineering 1
2. Claire	F	Black/African-American	Rising junior	Engineering 1
3. Lisa	F	White Non-Hispanic	Rising junior	Engineering 2
4. Sophia	F	White Non-Hispanic	Rising junior	Engineering 2
5. Rebecca	F	Black/African-American	Rising junior	Chemistry 1
6. Erin	F	White Non-Hispanic	Rising senior	Chemistry 1
7. Emma	F	Black/African-American	Rising junior	Chemistry 2
8. Amber	F	White Non-Hispanic	Rising senior	Chemistry 2

Note: All participant names are pseudonyms.

research in ways that might impact the investigated outcomes. Rather than pay tuition, each participant received a $200.00 stipend to participate for 2 weeks. The format for the program was a day camp where the eight students, grouped in pairs, went to either an engineering laboratory or a chemistry laboratory. They worked for five of the seven program hours most days supporting the ongoing research of the professional laboratories. Though participants spent the majority of their time in the laboratories, their schedule allotted time upon arrival, after lunch, and at the conclusion of the day's activities for explicit and reflective discussions related to their work in the laboratories, NOS, STEM careers, issues of identity, and to reflect on the day's activities. For example, students completed a NOS card sort similar to that by Cobern and Loving (1998), engaged in a problem-based learning activity related to energy needs, discussed the STEM career path with a female engineer, were given specific NOS-related questions to ask to their mentors, were given readings from a workbook related to research in STEM disciplines (Harland, 2011), and reflected on their most salient personal identities. Additionally, early in the program, all students went on a field trip to an algal farm.

Field trip. On the second day of the program, students participated in a field trip to an algal farm. Researchers from the university laboratories to which the participants were assigned conducted much of their field research at this farm. During an initial planning meeting with the scientists, the research team decided that visiting the farm at the beginning of the program would illuminate the interconnection between the various laboratory research experiences in which the students were involved. More specifically, researchers hoped that this field trip would provide participants with an understanding of where and how algae is grown and subsequently transformed into biofuels in addition to providing the participants with an understanding that the work itself was a product of years of collaboration between scientists and engineers. This was believed to potentially help the students situate the overall biofuels research in a broader context.

The algal farm was located far from the university campus in a rural area. The entrance to the farm donned 'Authorized Personnel Only' signs and was accessible by a dirt road. Scientists working in the field that day provided participants a tour of the entire facility. The tour covered many topics. (e.g. how an aeration system keeps the algae afloat, the monitoring of nutrients in the ponds, the desired level of algae growth, the polymer used to collect the algae, etc.) Students observed how the scientists collected and dried algae, and viewed the biodiesel reactor in which algae was converted into biodiesel on site. Hot summer temperatures and the smell of decomposing algae provided a revealing context for the participants. The students asked and inspired many questions.

Laboratory work. The research team randomly assigned the students into groups of two. Then, they randomly assigned each group of two to a mentor in one of two different laboratory settings. Two groups were stationed in chemistry laboratories and two groups were stationed in an environmental engineering laboratory. While this was the original plan for mentor and group assignments, researchers quickly noticed that the pairings did not always stay together and sometimes the pairings joined with another group. For example, on day three, students in the engineering lab were observed as a group of four operating under one mentor. In one chemistry grouping, graduate researchers split the pairing and independently worked with one participant each. Graduate student laboratory workers typically provided mentorship to the students. They encouraged students to take active roles in the everyday working activities of the laboratory, which more often than not involved preparatory work. Table 2 provides more detail on these groupings and describes the different activities observed in each laboratory setting.

One of the unique aspects of this apprenticeship was that though the laboratories were different (not even in the same buildings), they were all working on some aspect of biofuels research. For example, one laboratory goal was to develop a more efficient method to create biofuel from algae; another was to find out ways of utilizing bi-products of biodiesel production. However, one should notice that the activities in which the participants were involved were very diverse across their respective settings. While Emma and Amber were involved in the preparation of samples for polymerase chain reaction (PCR) analyses, Rebecca and Erin were observed setting up and running tests of elemental analysis (EA). Nearly every day when students came together into a whole group, students asked each other what they did in their laboratories. They were seldom doing the same thing.

In both the chemistry and the engineering contexts there was great international diversity among the graduate assistants and the faculty. In the chemistry laboratories there were three mentors working directly with four of our participants. Two mentors were females while one was male. In neither the chemistry nor the engineering contexts were there any Black/African-American graduate students or faculty members working when the participants were present. Also, besides the program participants, the engineering lab consisted of only males. This is important to note, since our participants were mostly female and half were Black/African-American.

Data Collection

In order to investigate NOS and inquiry understandings, we administered a form of the views of NOS (VNOS) questionnaire (Lederman et al., 2002) and interviewed our participants on the first day and on the last day of the program regarding their responses to this questionnaire as part of the semi-structured interviews to be described below. The items of the questionnaire were collated from multiple versions of the VNOS (i.e. B (as modified by Bell et al., 2003), C, D+) (Bell et al., 2003; Lederman et al., 2002; Views of Nature of Science [VNOS-D+], n.d.). The questions were drawn primarily from the VNOS-D+. We selected specific questions based on NOS aspects that we believed had the most potential to be impacted through participation in the apprenticeship program (Burgin & Sadler, 2013c). These questions were primarily related to student understandings of the empirical NOS, creative NOS,

Table 2. Laboratory activity details by student and group

Laboratory group	Participants	Mentorship	Collaboration	Activities
Engineering 1	Jacob	PI: Dr. Sarrat	Both engineering groups always observed working together	Took algae samples
	Claire	Grad student: Brian		Made BG11
				Measuring and prepping materials for use. TSS analysis Used Gas Chromatographer
Engineering 2	Lisa Sophia	PI: Dr. Sarrat Grad students: Louis and Ryan	See above	See above
Chemistry 1	Rebecca	PI: Dr. Orugi	Observed once working as a pair and then always working independently	Acid bath sterilization
		Grad student: Cassidy		Rinsing and combusting glassware
				Reactor preparation EA
Chemistry 1	Erin	PI: Dr. Orugi Grad student: Preston	See above	Acid bath sterilization Rinsing and combusting glassware
				Reactor preparation EA
Chemistry 2	Emma	PI: Dr. Gustar	Observed working as a pair	Calibrating instruments Transferring pipettes
	Amber	Grad student: Leslie		Prepping for PCR analysis
				Prepping controls for the experiment: measuring media Using the centrifuge

Notes: PI, principal investigator; BG11, medium for blue-green algae; TSS, total suspended solid; EA, elemental analysis; PCR, polymerase chain reaction. All participant names are pseudonyms.

subjective NOS, tentative NOS, social and cultural-embeddedness of NOS, and the myth of the scientific method (an aspect related to understandings of scientific inquiry). The questionnaire is available in Appendix 1.

Through two individual semi-structured interviews (one on the first day and one on the last day of the program), we examined NOS understandings by following up on written VNOS responses, and explored the identity and future STEM plans of our participants (Appendix 2). Specifically, interviewers asked students about their personal views of themselves and how others perceive them, their abilities to work in the laboratory environment, their self-positioning as a member within their working laboratory group, their future plans, and how this program related to and/or influenced any of the targeted outcomes of participation. Many of the questions we asked were based on and drawn from interview protocols from previous research that we have conducted in other research apprenticeship programs (Burgin et al., 2012). We supplemented the interview data by administering a focus group interview in which students collectively shared their ideas related to the work they were doing and their notions of belonging. Mentor interview data, and data collected as students were observed working in their laboratory placements were other secondary data sources.

Data Analysis

This study followed what could be considered to be a qualitative case study design. A case study approach situates and bounds understandings of phenomenon within authentic contexts (Yin, 2014). In this case study, the overall case (*the apprenticeship program*) was centered on how the participants of the program constructed their experiences working with their mentors and within the laboratories and the possible impact of those experiences. We then examined multiple cases bound within the overall case on the level of laboratory disciplines and pairings of students within them. Our study contains features of both descriptive and explanatory case studies (Yin, 2014). The analysis of our data was guided by both typological analysis (Hatch, 2002) in that the VNOS questions and interview questions that we asked and subsequently coded were guided by research-informed a priori units related to, among other things, NOS aspects, belonging, mentorship, abilities, identities, and future plans in addition to more inductive naturalistic modes of inquiry allowing for unplanned emergent themes (Lincoln & Guba, 1985).

Regarding participant NOS and inquiry perspectives, two researchers independently analyzed the written VNOS data and then held consensus building discussions in which they reached agreement on all ratings of either mixed, informed, naïve, or unknown for each NOS aspect assessed. This process was guided by the recommendations for analysis provided by the developers of the VNOS instrument (Lederman et al., 2002). The same two researchers held a separate meeting in which they discussed the interview data related to participant VNOS responses and allowed that data to influence overall participant profiles of NOS understandings at the beginning and at the end of the program that were more informed as a result of the additional interview data.

In order to examine participant identities and future plans, the three authors independently analyzed four of the first eight early-experience individual semi-structured interviews. During this initial process, data were labeled and arranged into provisional themes. The research team then met to discuss the themes that were emerging from the data. Following this, the authors divided the eight participants among them and each prepared a comprehensive analysis summary of all the interview data (interviews one and two) for their assigned participants. These summaries contained major themes and representative quotes that emerged from the interview data as they related to ideas of identity and future plans. These summaries were then distributed among the entire research team for feedback.

We then followed a process of explanation building in which assertions were made and then compared among multiple cases and multiple groupings of those individual cases (Yin, 2014). The lead author took the individual comprehensive analysis summaries and the VNOS analysis and prepared an overall report that described and explained the phenomenon (the influence of the program on targeted aspects) collectively by discussing the findings from the eight students as a whole group, comparing the summaries of the four students in science settings with the summaries of the four students in engineering settings, and then comparing the summaries of participants who were paired in the same laboratory. Thus, our cases were bounded in multiple ways (i.e. the program as a whole, individuals within the same discipline, and individuals within the same lab). This overall report was distributed among the entire team for their input and feedback. This report was used to form the basis of our interpretations that were then re-checked against interview data and other relevant secondary data sources in a manner consistent with methods of constant comparison (Corbin & Strauss, 2008). The focus group interview, observational data, and mentor interview data were used as secondary data sources to validate and supplement some of the understandings that were emerging from our analysis of the primary interview data. This analysis resulted in us looking at our data in new ways as we sought to examine participants' self-positioning within their assigned laboratory groups and to explain the possible relationship between those understandings of belonging and the impact of the program on the target student outcomes of NOS and inquiry understandings, identity, and future plans.

Findings

The following sections are organized by our research questions. First, we report on the impact of the program on the investigated outcomes for the participating students. Following this, we discuss findings related to the positioning of our students within their laboratory groups. These findings are related to ideas of enculturation and belonging within communities of practices. In this section we include a vignette regarding the differences in belonging as expressed by two of our program participants who were placed in the same laboratory group. We conclude by examining the relationship between positioning in laboratory groups and the investigated outcomes.

Understandings of NOS and Inquiry

Participant understandings of NOS and inquiry showed subtle positive shifts over the course of the program. Students in both the engineering and the chemistry groups experienced growth in their understandings of the empirical NOS, the social and cultural embeddedness of science, the tentative NOS, and the myth of the scientific method as revealed by their written VNOS responses and follow-up interviews. Of the 29 opportunities for growth in an individual's understanding of an NOS aspect, growth was evident on 17 occasions, 10 of which resulted in an informed perspective. However, there were 12 opportunities for growth where none occurred over the program. This speaks to a resistance to changing NOS ideas among our participants and hence our classification of 'subtle' growth. That being said, understandings of the creative NOS, the social and cultural-embeddedness of science, and the myth of the scientific method were often informed by participant experiences in the lab. For the students where this was the case, they experienced a science in action that relied on creativity throughout as procedures were carried out that might not need to follow the traditional scientific method. Students also saw the societal influences that were driving the biofuels research being performed. Table 3 displays the specific details regarding the NOS aspects that individual participants better understood at the end of the experience in addition to those aspects that were informed by their laboratory experiences (including the nature of the research that was conducted within

Table 3. NOS changes and laboratory-informed examples as revealed on the written VNOS questionnaire and supplemented by follow-up interviews

Participant	NOS aspects better understood at the end of the program	NOS aspects informed by laboratory experiences at the end of the program
Jacob	Empirical, creative, social and cultural-embeddedness, myth of the scientific method	Creative, myth of the scientific method
Claire	Empirical, myth of the scientific method	Creative, myth of the scientific method
Lisa	Social and cultural-embeddedness, tentative	Social and cultural-embeddedness, myth of the scientific method
Sophia	Subjective, myth of the scientific method	
Rebecca	Empirical, myth of the scientific method	Creative, social and cultural-embeddedness, myth of the scientific method
Erin	Myth of the scientific method	Social and cultural-embeddedness, myth of the scientific method
Emma	Empirical, social and cultural-embeddedness, myth of the scientific method	Social and cultural-embeddedness, tentative, myth of the scientific method
Amber	Tentative	Creative, social and cultural-embeddedness, myth of the scientific method

those laboratories, and the conversations students had with their mentors). As a precautionary note, for the sake of simplicity, we do not include the individual ratings of naïve, mixed, informed, or unknown for each aspect on this table. Therefore, a growth from naïve to mixed or from mixed to informed is reported on this table in the same way as is a change from naïve to informed (Table 3).

While we do think that any growth in NOS understandings of program participants has the potential to be overstated especially due to the short timeframe of the program, we were encouraged that many mixed and informed understandings at the end of the 2 weeks were described in terms of laboratory experiences within the apprenticeship program. We believe that a certain depth to the students' responses after the experience as revealed by the inclusion of specific examples from their laboratory experiences may be representative of growth in understandings of these NOS aspects. For example, Erin's understandings regarding the socially and culturally embedded NOS were unable to be rated before the experience. However, after the program she was able to express herself eloquently about the relationship between biofuels research as driven by societal needs and the interests of the STEM researchers.

> If society all of a sudden feels like they want to be environmentally conscious, that's what we're going to go into, like biofuels. We needed—We were worried about having an energy crisis. We were worried about pollution, so here's the biofuels, and it just kind of magically appears. And it not only depends on what the general society feels as a whole, but individual people have different things to bring to the table, and backgrounds definitely make a difference of what someone has to bring to the table. (Erin, second interview)

We contend that perhaps Erin did demonstrate some level of growth in her understanding of this NOS aspect because of how her understanding was rooted in the nature of the research being conducted in her laboratory. Interestingly, Sophia in particular identified the laboratory as the reason for any changes in her NOS understandings. 'I think actually experiencing it, like being there and doing some of the stuff that real scientists do in the lab changed my ideas about it, because unless you're there, you won't really understand' (Sophia, second interview). We find this interesting because we did not note any specific examples from her laboratory placement related to the NOS aspects that she understood in more sophisticated ways at the end of the experience.

Also worth mentioning is that Lisa and Amber in their pre-experience VNOS interviews specifically mentioned that they noticed that research posters displayed in the halls did not contain hypotheses while on a tour of their laboratory placements. This led them to believe that this research may not have strictly followed 'the scientific method'. However, this visit to the laboratory took place between the administration of the written VNOS and the follow-up interview. Amber's written data did reveal growth in her understandings of the myth of the scientific method.

> All scientific investigations may not follow the scientific method depending on the implied definition of a scientific investigation. For example in the lab I was in, (my mentor) was simply attempting to successfully transform algae. There was no clear independent variable, and the dependent variable was either successful or unsuccessful. She knows it can be transformed so she needed not hypothesize her outcome. (Amber, Post-Questionnaire)

Perhaps student views of this aspect were being shaped almost immediately upon beginning participation in this program. While three of the four engineering students (Jacob, Claire, and Sophia) experienced growth in their understandings of the scientific method, none of them exhibited an informed perspective at the end. Jacob told us that one of the mentors of these students (who worked with all four students) specifically talked about the importance of following the scientific method. However, this mentor did mention, according to Jacob, that if the scientific method is not followed, then 'you must justify your answers another way'. It follows that these three participants left with an understanding that there are other ways to do science even if the scientific method was preferred.

Future Aspirations

With the possible exceptions of Rebecca and Lisa, all students entered with a desire to pursue STEM-related futures. That being said, Jacob, Sophia, and Erin seem to have had their interests in pursuing STEM in college and in future careers solidified and/or expanded. Jacob in his second interview said, 'Well, it helps to solidify what career I wanted to be in. I've always wanted to be in a STEM career'. Early in the program, Jacob, who wanted to be in the medical field, noted that, 'I want to pursue a career in science. I'm trying to get as much science under my belt as possible to look good on a resume, and I enjoy this. I enjoy going to camps like these'. In addition, Sophia talked about an expansion of her career possibilities as she was exposed to engineering disciplines she had not considered. Below we present a number of student quotes from interview data that represent their perspectives regarding how their future plans were being shaped by the program.

> I learned a lot about the different careers in the STEM field and how I don't have to stick to one particular career just by what I want, because I like science, and there are a whole bunch of different careers in science ... Being in the labs was very cool and exciting and it opened up my mind about all the different science careers and all the different engineering careers. I think this program will help me choose a career in a STEM field. (Sophia, second interview)
>
> And since I understood most of it, I think that it was pretty solid that a STEM field was where I was meant to be. And seeing the workplace is a lot different than being told about the workplace ... I think I'm going to be severely interested in working in the lab, and I'm one of those people that if I'm not there to work, then I shouldn't be there at all. (Erin, second interview)

Amber, a self-described future science teacher (which we are considering an important STEM-related future), discussed how the experience had the potential to be very important to her future pedagogical practices.

> It relates to my future plans in that, like I said, I think that it enhances my, or any other teacher-to-be's, ability to teach ... it is always good to experience firsthand, and I almost feel like that should be a requirement ... I feel like whatever you're teaching, you should have some kind of practical experience in that field ... Because they're going to have a richer comprehension ... I now have a richer comprehension of bacterial transformation. (Amber, second interview)

However, not all students were similarly impacted. Claire, who wanted to be either a forensic scientist or a pharmacist, and Lisa, who wanted to be a psychologist, recognized that laboratory work and fieldwork specifically related to biofuels just was not for them.

> I used to think that I wanted to be in a lab, but I don't really think that is for me anymore … I wouldn't mind working in a forensics lab … I want to do pharmacy and forensics. (Claire, second interview)

For Claire, specifically, this lack of desire to be in a laboratory was specifically tied to her experiences in the engineering laboratories where there was a lot of down time waiting for investigations to come to completion. In other words, while she still saw laboratory work as a possibility for her in general, she did not want to work in an engineering laboratory similar to the one she worked in.

> Being somebody that would go into the field as far as like working with biofuels and algae farms, not for me, definitely not … no, no heat like that. No outside conditions. No, I'm an indoor, AC kind of person. (Lisa, second interview)

Rebecca, who, as will be discussed later, was not pleased with her laboratory placement, specifically said that the 'possibility for science' was 'opened up' through this experience. We find this fascinating given her troubles assimilating into her laboratory group culture. That being said, she did say that she would not want to work in a laboratory as part of her career and still held on to the possibility of becoming a Lawyer.

> I think I would like working in a lab, but not like for as a career. I think I would still want to be a lawyer. I think it opened up the possibility for science. It might have like, not shifted them, but like opened it up, gave me a different outlook on science. That was on the first day/It was like, it was positive, because like on the first day, I was like, oh wow, so science isn't just like some boring thing. Like it's actually fun doing stuff like this. So I actually liked it. (Rebecca, second interview)

Identity

Jacob, Claire, Sophia, Erin, and Emma in particular described how they learned about themselves through the apprenticeship program (i.e. minority, gender, other characteristics of self) and/or how their self-recognized salient identities related to their positioning within the STEM community. Jacob, when discussing his experience, in his second interview told us, 'It made me feel like I was trusted or I wasn't just a little kid, a high schooler coming to a college campus and working … doing busy work'. Early in the program, he expressed his concerns about other males participating in STEM programs. He asserted, 'I don't think males really try to achieve higher science classes or ones that [are] off track from normal core classes, like… chemistry and stuff like biotech'. He further claimed that he saw his identity differently, 'within the science field, I think I am well suited for it'. He also spoke of a lack of African-American male doctors, a profession he was pursuing. Claire, an

African-American female, talked about how her personal identity related to her STEM-related aspirations in her first interview when she told us, 'Most African Americans don't major in science. They are trying to do things like basketball, and football, and sports things that don't really matter'. She went on to say in her second interview that the experience, 'helped me somewhat understand who I am in a way, or at least make me aware of like who I am or like how I would be different from someone else'. Sophia described how the experience helped her learn more about herself in her second interview when she said, 'They've [discussions during the program] helped me learn a little bit more about myself'. Below are some additionally relevant interview excerpts regarding identity from our participants.

> Erin: I'm very confident about what I'm doing.
> Researcher: Okay. So has that changed your overall perspective of how you see yourself?
> Erin: Yeah, I've noticed a lot that as long as someone can explain it to me once, I got this. And it's very empowering—To notice that I can keep up with the ball game. (Erin, second interview)
> Researcher: Okay. You had mentioned to me there were five things that you could say now about your identity.
> Emma: Oh my gosh. (laughs) Yes. I could say—Okay, my number one is student, because there's always something that I can learn from anybody, like even off the street. I don't have to be in school ... So I say student, and then I say a female, and then I say African-American, and then I wanted to throw in twin, because there's not a lot of twins, so—And then what is another one? I was going to say, oh, a future scientist ... or a scientist in the making ... I wouldn't think about identity, so I mean, it kind of—It was an eye-opening—So I had to like realize, oh, I don't know, so maybe I should start thinking about that, and try to figure out who I am ... I learned about my identity. (Emma, second interview)

For these participants, the apprenticeship program encouraged exploration, introspection, and discussion of their self-identity as they tried to figure out how those identities fit in with their future plans as related to the biofuels research they were participating in during the program.

Positioning Within Laboratory Placements

While our students were involved in the everyday activities of their laboratories (see Table 2), we noted that the work that they were doing was limited in large part due to the short duration of the program and the constraints of what was taking place during the 2-week period of time that coincided with our program. For example, Leslie, a graduate student mentor for one of the chemistry groups, told us during her mentor interview that the work of the students was valuable to her in that 'it was a great help because it would save me time because I could get on with like my actual research that I wanted to do and I could give them more of the prep work'. When we asked her why they did not do much more than prep work, Leslie replied that it was due to 'where her research was at the point [of the program]'. She did say that she trusted the work that the students did.

Variation in the activities that students engaged in was evident when comparing the experiences in the engineering and chemistry contexts. Students in the engineering groups (Jacob, Claire, Lisa, and Sophia) were often involved in observing and shadowing the researchers rather than engaging in meaningful research, which resulted in our observations of periods of down time for the students. For example, observers of the engineering group seldom noted that participants were conducting science investigations on their own or under the supervision of their mentors. When they were, for example, they were performing routine analyses of total suspended solids (TSSs). Perhaps this was due to the realities of the potential dangers of the equipment in the laboratory (i.e. batch reactor). One of the mentors in the engineering lab told us that, 'We didn't want them to, I don't know, for them to take any risks, you know' (Brian, mentor interview). Another mentor in this lab said that intentionally, 'We just tried to involve them in very basic, like basic analysis' (Louis, mentor interview). However, at the end of the experience the mentors in the engineering laboratories were impressed with the participants and thought that they could have been involved in even more valuable work than they were.

> Maybe our expectations also were kind of lower to whatever they proved being capable of, so now that I think it over … We could have asked them to do more serious jobs … more specific tasks. (Brian, mentor interview)

In contrast, students in the chemistry groups (Rebecca, Erin, Emma, and Amber) were more included in what we believed to be meaningful research processes that involved the setting up of apparatus, the preparation of samples, and the collection of data. When observed, students in the chemistry labs were always active. Whether they were sterilizing equipment, prepping for PCR analysis, prepping for and running EA, or recording data, students were involved in authentic laboratory work constantly. This group also tended to worry more than the engineering group about getting to the lab in time. They felt like they needed to get back in order to complete their work or to make sure they could help out. This speaks to the individual engagement of the students in the work that they were doing.

Belonging. Students' positioning with their laboratory groups were classified in terms of feelings of belonging within them. Jacob, Sophia, Lisa, Erin, Emma, and Amber clearly expressed that they felt positively about their own belonging within their laboratory group and that what they were doing was important and mattered, even if they felt that they were in between being a working contributor and a visitor to the lab. These students felt that they were making significant contributions to the work of their laboratory groups. It should be noted that this was often the case even when, likely due to time constraints (2 weeks), the students were typically involved in equipment sterilization and sample preparation at the expense of data collection and analysis. Below are some representative interview excerpts for this aspect.

> Because I felt I wasn't an outsider, that I actually contributed to their research and helped them get closer to their goal . . . . It made me feel like I was a part of the—like it wasn't just a program or a camp where like they were babysitting us. We were actually doing—they [Mentors] would be at their computer doing research and we'd be all in another lab helping them with tests without supervision. They trusted us with their data and information. (Jacob, second interview)
>
> He would help us learn, and then he would show us what to do, and we would do some of the stuff ourselves, and we would help him, and I thought that I was a working contributor, but I wasn't doing everything by myself. I was there to learn, too. (Sophia, second interview)
>
> If somebody needed us to clean something, we were like, okay, cool, no problem ... I think [my mentor] was almost going to cry when we left. (laughs) It was kind of sad. But you know, it was just—I felt like I actually was a part, and that I felt like—kind of like in a family, so to speak. (Lisa, second interview)

Additionally, Lisa and Sophia specifically felt they were a part of the laboratory team as evidenced by their comments about being invited to team meetings. Lisa talked excitedly about being 'invited into the circle' when describing these meetings.

> I got super excited, and that almost made my entire day, because I have at least 25 samples in there that I helped worked with him with, and they have [my name] on them, and it's just so exciting, because I made that much of a contribution to even have my name on some of the stuff that's going to be there for, you know, five years being worked on. (Erin, second interview)
>
> She can trust us now, because we know how to do it, since we've been there. So she [my mentor] just sat and watched us, and we got and did everything right. (Emma, second interview)

Amber (a member of the chemistry groups and future teacher) took advantage of opportunities in her laboratory to practice teaching by answering Emma's (her laboratory partner's) questions. Additionally, she said that she experienced more belonging than did students in the engineering groups do to the nature of the work that she was involved in. She went so far as to describe this as being a 'disadvantage' to the other students.

> I would say I felt like the engineering labs were a little bit disadvantaged with their experience ... because Leslie [my graduate student mentor] was just so incredibly accommodating ... It was almost never, you can observe, because I have something I have to do, you know? It was always, we're going to do this. We are. And I feel like that may not have been present all the time in all the other labs, and I feel like that was important. (Amber, second interview)

Claire (a member of the engineering group) clearly articulated that she felt that had there been more for her to do in the laboratory, as was the case with students in the chemistry groups, she may have felt more valued.

> Our lab was more relaxed. It didn't really have a lot going on. And I think other labs were constantly active based on what they tell us through the discussions. But yeah. Because I said I'm an active person, I would kind of want to see what the other labs would be like if I was in it and to have like how Erin said, [her mentor] depends on her for certain stuff. (Claire, second interview)

However, not all students in the chemistry laboratories felt like they belonged or that the work that they were engaged in was meaningful. As will be discussed shortly in a vignette, Rebecca resented the amount of time she spent sterilizing glassware.

Confidence. Along with feelings of belonging seemed to come an air of self-confidence in participants' laboratory capabilities. Three students (Sophia, Lisa, and Erin) in particular explicitly expressed a confidence regarding their abilities to function in the lab that developed over the course of the program. This is represented in the following interview quotes.

> And I think helping them made things go a little quicker and learning this helped them feel like they were teaching us, and made me feel confident, and made them feel confident, I guess, to have us there so that we could work. And I do believe that it was significant because we did a lot to help them. (Sophia, second interview)

'I mean I'm definitely more confident that I know what I'm doing now' (Lisa, second interview). 'I'm very confident about what I'm doing' (Erin, second interview). The confidence expressed by these students seemed to be mitigated by their positive feelings of belonging within the laboratory group. They felt that their work was at least to a certain extent valued by their mentors and important to the group as a whole and therefore they expressed a confidence in their abilities to make meaningful contributions.

Erin and Rebecca: A vignette

The work that students performed in the laboratories, their sense of belonging within those laboratories, and their personal confidence to meaningfully contribute to the work occurring therein seemed to be mediators of successful border crossings (Aikenhead, 1996) between experiences in home life and school science and the workings of a professional laboratory. As an example of this, we present two contrasting stories of students (Erin and Rebecca) who, while placed in the same laboratory group, had very different experiences likely due in part to being mentored by two different people.

Erin's experience regarding her enculturation into the chemistry laboratory has already been previously documented in this manuscript and, as such, her story, as told here, will be briefer than Rebecca's. Erin felt a strong sense of belonging and worth in her laboratory group and she felt an 'empowering' confidence in her self-abilities and understood the importance of the work she was doing. Our observations corroborate this in that Erin experienced the most authentic and engaging research in action and arguably had the most positive relationship with her mentor. Erin's mentor, Preston, described the value of her contributions in the following way as he described how her work was of use even after the program concluded.

> At the end … the work that she helped me with (and I had to add some extra experiments after she left), we presented that in a conference. So part of the work that she did was presented in a conference. (Preston, mentor interview)

In comparison to Erin's experience, Rebecca's enculturation within the laboratory group was not so seamless. Though she mentioned that she did well in school science, it seemed that in the laboratory she was not able to attain a role similar to the one she enjoyed in school. Rebecca spoke of her role in school as a highly respected go-getter. She seemed comfortable and proud of this role.

> And then I'm president of my class, and I'm in so many different groups and volunteering and stuff. It's like very time consuming. You've got to make sure this doesn't go over this and that, so it's kind of hard. I don't know, everybody just thinks that I'm so, so smart and that everything comes so easily to me. (Rebecca, first interview)

In her second interview, Rebecca exuded a certain sense of disappointment in her placement and the activities that she was engaged with. She even wondered if her mentor viewed her as capable.

> I don't know if she felt like I wasn't capable of doing it, but Cassidy [my mentor] is more of an informative person, so she tries to explain every single thing, like even now to the aspect of cleaning. She tries to explain every single thing, and Preston [Erin's mentor] is more like, here, I'll explain it a little bit, I'll show you how to do it, you do it yourself. And so with her, she was just like, oh, maybe you can wash this part. Maybe you can wash this part ... so I just got penned off. (Rebecca, second interview)

The role that Rebecca played in the laboratory was not like the one she played in school. The process of enculturation and belonging in her laboratory was therefore difficult for her.

As previously alluded to, Rebecca, in contrast to Erin, was most often delegated to preparatory work for investigations which (due to the nature of the research being performed) involved sterilization or as it was described by the participant, 'cleaning'. She viewed cleaning or sterilization as a hierarchically substandard task, and as a result said that her experience was not what she was expecting.

> I think—I don't think it was like a boring thing, because it's better than being at home, but at the same time, I was just like—I kind of didn't come here for this, but—so I was just like, okay. I'll stick it out, I guess. Not necessarily stick it out, but I guess that's what it is. (Rebecca, second interview)
> It didn't feel like a mentorship. (Rebecca, second interview)

Rebecca clearly resented 'cleaning' and emphasized it pervasively in her second interview at the expense of other tasks she was engaged in. Indeed, over the course of the program, we only observed Rebecca cleaning once, and did observe her engaged in other tasks. Cassidy did report that in addition to cleaning, Rebecca was involved in helping 'prep EA samples which were needed ... determining and prepping some samples that we needed to figure out the algae content for' on multiple occasions. While Rebecca certainly did not appreciate the amount of sterilization she did, she was able to explain in detail the process of the 'cleaning' in which she was engaged, which likely indicated a certain understanding of the importance of this task.

> And I learned how to combust different things after cleaning it, because there's a cleaning process ... You put it in an acid bath for 12 hours, take it out the next morening. You've got to rinse it three times, and then you put it in the oven, then you wrap foil around the glass, and you put it in the combustion oven for like 12 more hours ... so I learned the process. (Rebecca, second interview).

Cassidy (Rebecca's mentor) explained the importance of cleaning through a process nearly identical to what Rebecca told us. This indicates that Rebecca likely learned from her mentor about this process during the course of the apprenticeship.

> In our lab, we're working with organic material, we're adamant and particular about the way we clean our glassware ... We have to soak it in acid for 12 hours and you dry it, then you combust it for 12 hours ... you're not doing that in a high school level or an undergrad level [laboratory] ... And that was just the point that I was trying to make to Rebecca ... that this is part of the planning (Cassidy, mentor interview).

It is interesting that Rebecca and Erin experienced such different feelings of belonging while working within the same laboratory. An important difference in their environment was that they were the only two participants working solely with their own mentor. Though they did not work together, they could still see what the other was doing. In the same way, each of the mentors was able to view the other mentor working with their apprentice. This seemed to enable and possibly encourage both participants and mentors to compare their experiences. Rebecca often compared the work in which she was involved with what Erin was doing.

> I'd say, on the third day there, Erin was doing the same exact things as the high school student [a volunteer independent from our program] who had been there for like a month, she was doing the same exact thing. So I was like, if she could do it, why couldn't I, but—I was cleaning. (Rebecca, second interview)

Rebecca also compared her mentor to Erin's.

> She [Rebecca's mentor] tries to explain every single thing, and he [Erin's mentor] is more like, here, I'll explain it a little bit, I'll show you how to do it, you do it yourself. (Rebecca, second interview)

Rebecca told us that she felt like her mentor was 'mean' and subsequently did not feel the same belonging within her lab as did Erin. When pressed about whether she thought this had anything to do with her ethnicity during her interview, she was quick to dismiss such a notion when she expressed that her mentor was similarly 'mean' to everyone.

> I was like maybe the only black person that actually worked in there for real. Everybody else was like—either like foreign or like white, but she (her mentor) was like loud and mean to everybody. (Rebecca, second interview)

These comparisons seemed to negatively skew Rebecca's perceptions of her experience within the lab. However, from our observations and from participants' interviews, Rebecca's experience was more authentic than that of the engineering lab participants. Although she did spend time sterilizing equipment, she also seemed to spend more time than others recording data and performing scientific tests. Yet when she compared her experience with Erin's she felt shortchanged.

In the same way Rebecca's mentor also compared Rebecca and Erin.

> I wasn't getting any of those questions from Rebecca, it was just kind of show up, do the work. She was interested and polite, I just don't think she was really as committed as maybe Erin was. (Cassidy interview)

Cassidy also felt that Rebecca was not as 'enthusiastic about science' as Rebecca was. Her comparison of Rebecca and Erin could have impacted the work she gave Rebecca. It was noticeable that the connection between Rebecca and her mentor was not as positive as that of Erin and her mentor.

Relationship Between Positioning and Outcomes

In the section that follows, we describe our analysis of the data in order to examine relationships among student positioning in laboratory placements and the investigated outcomes. First, we want to say that this relationship was a complex one and that there were individual exceptions to every generality. For example, Claire and Rebecca felt the lowest levels of belonging within their laboratories, yet still learned about NOS. Additionally, Claire learned about her self-identity during the program. Perhaps that is because we explicitly examined these features outside of the laboratory time through activities and group discussions. However, given that so many of our participants' post-experience NOS views were informed by the laboratory work that they were engaged in, we believe that more engagement in those authentic research activities could have resulted in deeper understandings of the epistemological considerations (NOS understandings) that guided the work they were doing.

Additionally, we found that when a participant was engaged in the authentic work of the lab then they had the potential to develop a stronger sense of belonging and subsequently more confidence in themselves. This likely resulted in a strengthening of the participants' personal identities as they related to science and could have further solidified their desires to pursue STEM-related careers. For example, Claire felt unengaged in her laboratory and subsequently did not want to work in a similar environment in the future. In contrast, Erin felt engaged in her laboratory, confident in the work that she was doing, and described a belonging within the group. She also exhibited a solidified desire to pursue STEM and felt empowered about her self-identity as it related to meaningful contributions with the STEM community. Similarly, Jacob felt engaged in meaningful laboratory work (even if our observations led us to question the importance and value of that work), and a real sense of belonging within that group. His future aspirations and his notions of self seem to have been subsequently influenced as a result of participation in the program.

As previously mentioned, there were exceptions to the relationships described above. For example, Sophia, like the other engineering students, was not engaged in as meaningful of work as some of the chemistry students were, but did demonstrate positive outcomes (most notably on her future plans). Perhaps this can be explained through her inclusion in the normal laboratory routine (i.e. laboratory group meetings) and the positive relationships she developed with her mentors and subsequent feelings of belonging and confidence. Sophia seemed to understand why her engagement was limited (i.e. dangerous equipment, time) and took advantage of the opportunities that were provided to her to participate in the laboratory work she was allowed to. However, Lisa was engaged in the same work as Sophia, felt a sense of belonging within her laboratory placement, and was confident in what she was doing, but demonstrated little by way of the investigated outcomes. Perhaps this is because her sense of self and future plans were more firmly solidified upon entering the program. Additionally, Rebecca, the least engaged student and the student who seemed to be the least satisfied with her mentor and likely the student with the lowest levels of belonging within the laboratory group, still felt encouraged to pursue a STEM-related future. She even applied to come back to the program the following summer. We would posit that Rebecca deep down understood why 'cleaning' was a necessity and saw her laboratory placement as just one example of an authentic professional STEM context and not necessarily one she would work in again.

Discussion

The findings of this study add to and refine multiple theoretical understandings within the science education community. First, this study lends credibility to notions of the potential of even very limited explicit/reflective NOS approaches within highly authentic inquiry-based contexts such as research apprenticeships, as well as the limitations of implicit NOS approaches (e.g. Bell et al., 2003). We found it remarkable that even in such a short period of time, NOS understandings of our participants were somewhat impacted. That many of these understandings were informed by the experiences in the laboratories speaks to the power of authentic experiences in scientific research as a context for reflection. This finding seems to corroborate the theoretical viewpoints of Sandoval (2005) as well as Duschl and Grandy (2013) regarding the importance of participating in the practices of science when learning about NOS. However, we do not disregard the viewpoint of Lederman (2007) that this should not be at the expense of explicit/reflective approaches. Many NOS viewpoints of our participants were not positively impacted over the 2 weeks. We wonder, if we had had more time to implement NOS instruction in an even more focused way, whether we would have seen more pronounced changes in the NOS understandings of our participants.

Second, the finding that although student contributions to the progress of their laboratory group's research (i.e. the generation of research questions and methods, decision making during data collection and analysis) were nearly absent with all of our participants (they were working on ongoing research projects for a short period of time) we still observed a positive impact of the program for multiple participants is a surprising one. Although we have observed a similar result in the past

(Burgin et al., 2012), this finding potentially challenges current understandings that place importance on epistemic demand in authentic STEM research (Bell et al., 2003; Burgin & Sadler, 2013c; Ryder & Leach, 1999). In other words, even an authentic context apart from authentic epistemically demanding work may have a powerful impact on students.

Third, our study contributes novel understandings related to the potential impact of short-term (2 weeks) exposure to professional STEM contexts. We do acknowledge that had the program been longer, perhaps students would have been able to contribute to the laboratory research in more significant ways. In fact, multiple mentors told us that if we do this again, our program should last for a significantly longer period of time for these reasons.

> Would I do [it] again if it was two weeks? Maybe. Would I do it again if it was more? Absolutely. Yes. (Preston, mentor interview)
> Did I find value in both of their [Erin and Rebecca's] presence, I would say yes, but I also feel like ... there could have been more value, just because mainly it was due to the time factor. It was only two weeks. (Cassidy, mentor interview)

Fourth, our study lends new understandings about the importance of students working collaboratively under the same mentor in terms of feelings of belonging. When Rebecca and Erin were isolated from each other, comparisons between both their mentors and experiences resulted in a less positive experience for Rebecca than for Erin. Additionally, when Amber was paired with Emma, Emma received mentorship from Amber in addition to others in the lab.

We close with a discussion of the diversity that the students encountered in their laboratory placements. Of the nine STEM professionals (three faculty members and six graduate students/laboratory personnel) that worked with and/or mentored our participants, only two were female and none were African-American. Additionally, during the field trip to the algae farm, one of the female participants boldly asked a scientist, 'Where are all the girls? Do girls ever work out here?' It was evident that our mostly female participants were already noticing the lack of gender diversity in this particular context. It is interesting that in spite of these demographic differences, multiple students expressed positive science self-identities and a feeling of belonging within the laboratories at the end of the program. That being said, the only two students who did not seem to feel a sense of belonging within their laboratory group were African-American females.

Future Research

It is our hope to expand this work into future investigations of similar apprenticeship experiences for underrepresented students. In particular, we are curious about the relationship between the timeframe of the program and the outcomes we noted. If the program had been longer, students perhaps would have been able to make more valuable contributions. There would have been time to put together a manuscript and/or presentation of their findings. Creating such a product may have resulted in participants taking more ownership over their project and hence they may have felt even more belonging within their laboratory placements.

We are also curious about the context of the research. Would we have observed the same results if students had been placed in a larger variety of laboratories that were investigating things other than biofuels? Or did the common research theme lead to more robust group discussions when all program participants were together?

Finally, we offered very little training to the mentor faculty and graduate students in our program. We are wondering what the impact would have been if we had truly offered them more robust experiences in preparation for hosting diverse high-school students in their lab.

Conclusion

As a result of our investigation, we believe that these sorts of authentic experiences offered over an abbreviated timeframe can be influential if the participants feel included and valued even when mainly being involved in sample preparation and observation of others performing authentic laboratory work. Thus, some of our participants effectively crossed a border (that between their home and school science experiences and the culture of a professional STEM community) in a relatively seamless and instantaneous way with the appropriate acceptance and inclusion by those mentoring them. This finding adds to understandings of cultural differences between students and the cultural norms present in various learning environments including those that are highly authentic (Aikenhead, 1996). The implications of this current study relate to the value of research apprenticeship experiences and the importance of recruiting diverse students to participate in similar out-of-school opportunities. We also acknowledge the need for future similar investigations, particularly those that focus on identity development.

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No potential conflict of interest was reported by the authors.

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Appendix 1. VNOS Questionnaire (Collated Questions from Various Versions of the VNOS; Bell et al., 2003; Lederman et al., 2002; VNOS-D+, n.d.)

(1) What is science?
(2) What makes science (or a scientific discipline such as physics, biology, etc.) different from other subject/disciplines (art, history, philosophy, etc.)?
(3) What is the scientific method? Do all scientific investigations follow the scientific method?. Defend your answer.
(4) Scientists try to find answers to their questions by doing investigations/experiments. Do you think that scientists use their imaginations and creativity when they do these investigations/experiments?
  (a) If NO, explain why.
  (b) If YES, in what part(s) of their investigations (planning, experimenting, making observations, analysis of data, interpretation, reporting results, etc.) do you think they use their imagination and creativity? Give examples if you can.
(5) (a) After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? Explain and give an example.
  (b) Do forms of scientific knowledge other than theories change in the future? Explain your answer and give an example.
(6) Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence do you think scientists used to determine what an atom looks like?
(7) The model of the inside of the Earth shows that the Earth is made up of layers called the crust, upper mantle, mantle, outer core, and the inner core. Does the model of the layers of the Earth *exactly* represent how the inside of the Earth looks? Explain your answer.
(8) (a) Scientists agree that about 65 million years ago dinosaurs became extinct. However, scientists disagree about what caused this to happen. Why do you think they disagree even though they all have the same information?
  (b) If a scientist wants to persuade other scientists of their theory of dinosaur extinction, what do they have to do to convince them? Explain your answer.
(9) Is there a relationship between science, society, and cultural values? If so, how? If not, why not? Explain and provide examples.

Appendix 2. Participant Interview Protocols

Semi-Structured Interview 1.

NOS

(1) Explain your responses to the written questionnaire items. Elaborate on what you have written.

Identity

(1) In regards to your academic abilities, how do you think most people perceive you?
(2) In regards to your academic abilities, how do you perceive yourself?
(3) Explain to me the reason (s) why you decided to attend a science program.
(4) What are three things that you would say describe your identity or who you are as a person (e.g. gender, race, etc.)?
(5) Please explain how you feel being a(n) (Male, Female, Black/African-American, White Non-Hispanic, etc.) in a science discipline.
(6) What are some of the positive factors of focusing on science as a future discipline of study?
(7) What are some of the negative factors of focusing on science as a future discipline of study?
(8) Do you think you will see yourself as a working contributor in the lab, an outsider just visiting, or something in between?
(9) One day do you think you will be a working contributor within STEM, an outsider, or something in between?
(10) How do you feel about your abilities to work in the lab that you have been assigned?
(11) How do you feel about your abilities to work within STEM in general?

Semi-Structured Interview 2.

NOS

(1) Explain your responses to the written questionnaire items. Elaborate on what you have written.
(2) Do you think your NOS ideas have changed over the two weeks here? How so?
(3) If you think your NOS ideas did change, what might have caused them to change?

Identity

(1) Explain to me if participating in this science program changed your views of yourself as a future scientist.
(2) Explain to me if participating in this science program changed your views of yourself in any way.

(3) What are some of the positive factors of focusing on science as a future discipline of study?
(4) What are some of the negative factors of focusing on science as a future discipline of study?
(5) Did you see yourself as a working contributor in the lab, an outsider just visiting, or something in between? Why? Explain the significance of the contributions that you were making.
(6) How do you feel about your abilities to work in the lab?

Future Plans

(1) What are your plans after high school?
(2) If you are going to college, what would you like to study?
(3) What professions are you considering?
(4) Do you see yourself studying/doing/participating in science in any way?
(5) Do you see this experience relating to your future plans in any way? How?
(6) Do you see this experience helping you as you pursue your future plans? How?
(7) Did this experience impact your future plans in any way? How?

Program

(1) Did the program impact anything other than NOS, Identity or Future plans for you? If so, describe.
(2) What parts of the program do you think were the most beneficial for you in general? Why?
(3) Do you have any suggestions for us as we consider offering the program again in the future?
(4) How do you plan on taking what you learned here back to your school next year?
(5) When asked to describe these two weeks to others and it meant to you, what would you say?
(6) Is there anything you would like to share that we haven't asked about yet? What?