Cultivating STEM Talent: Lessons from STEM Pioneers and Exemplar Institutions

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Abstract

This paper explores views of talent development among STEM faculty, program directors, and administrators from exemplary institutions in producing STEM bachelor's degrees. We explored this theme across three qualitative studies to determine how each institutional agent conceptualizes and cultivates student talent in introductory classrooms and in later undergraduate career stages. We also examine the institutional structures that support and coordinate these efforts. It is clear that the concept of talent development is shared by institutional agents, but is not widely accepted in STEM or in all introductory courses where it is needed the most. Faculty related how they identify and cultivate talents. Further, several institutional practices supported the efforts of institutional agents who utilized a talent development approach to student learning.

Introduction

Major reports have established national goals to increase the conferral of science, technology, engineering, and mathematics (STEM) degrees in order to broaden and diversify the STEM workforce (Olson & Riordan, 2012; NAS, 2011). Indeed, the ability of the nation to produce a diverse cadre of workers with core STEM competencies is vital (Bair & Haworth, 2004), as this pool of workers will drive technological and scientific innovation in critical areas such as energy, health, and environmental protection, and ultimately position the country as a global leader (Olson & Riordan, 2012). The purpose of this paper is to explore the views of student talent development among STEM faculty, program directors, and administrators in their respective fields in an effort to understand how they identify and develop talent with implications for science education and training. This work informs efforts to meet national goals of expanding and diversifying the scientific workforce.

Faculty are an integral component of campus efforts to increase the participation and retention of students, especially students who are from underrepresented racial minority (URM) backgrounds, in STEM disciplines. The provision of meaningful mentorship experiences (Borum & Walker, 2012) and opportunities for students to conduct research with faculty (Eagan, Hurtado, Chang, Garcia, Herrera, & Garibay, 2013; Jones, Barlow, & Villarejo, 2010; Pender, Marcotte, Santo Domingo, & Maton, 2010; Strayhorn, 2010) are two important ways faculty help STEM students realize their academic potential. Namely, these activities increase the likelihood students reach degree completion, graduate with a high GPA, and aspire to pursue a STEM career or graduate degree. Recent research on STEM faculty also focuses on classroom redesign initiatives in STEM classrooms such as active learning (Freeman, et al., 2014), and student-centered pedagogy (Wood, 2009), both of which seem to produce numerous benefits to students pursuing STEM majors.

While these research streams represent important steps in understanding how faculty help students complete their STEM degrees, faculty members' conception of scientific talent likely impacts their investment in efforts such as mentorship and research with undergraduates. Narrow definitions of talent, traditionally measured by exam scores or course grades, moderates the frequency by which faculty engage in these practices. Thus, if mindsets affect behaviors (Dweck, 2008), particularly investment in students' learning, it is important to understand faculty conceptions of student scientific talent. Further, narrow definitions of talent fail to acknowledge that students have unequal access to quality K-12 education and, yet are nonetheless excited about their respective STEM discipline, eager to learn, and have the potential to be productive professionals in the STEM enterprise.

The students who faculty identify as having talent are likely recipients of further investment by faculty with respect to the provision of affirming messages, mentorship, and co-curricular opportunities shown to support success (i.e. research, internships, and exposure to professional networks), and letters of recommendation. Relying on traditional notions of scientific talent to distribute enriching opportunities and further investments, likely results in a cycle of cumulative advantage for those identified as having talent. A cumulative advantage process is "capable of magnifying small differences over time and makes it difficult for an individual or group that is behind at a point in time in educational development…to catch up" (DiPrete & Eirich, 2006, p. 272), unless a faculty member or institutional agent recognizes talent and seeks to develop it further. Those who are not identified as having exceptional talent may be left to rely on personal savvy to survive in their undergraduate programs.

In order for faculty to better facilitate the progression of aspiring STEM students to STEM degree completion and beyond, it is essential that talent be viewed through a more expansive lens. Since institutional-wide practices (i.e. teaching practices and intervention programs in the learning environment) and normative contexts matter in the retention of STEM talent (Eagan et al., 2012; Haak et al., 2011), much can be learned by investigating how talent is identified by STEM professionals who have had a long career in STEM and by STEM educators at institutions that do a better than average job at producing STEM degrees among URM students considering the resources to which they have access. Further, there is little information on the institutional structures that support faculty in their efforts to cultivate talent or how campuses coordinate individual and organizational efforts to engage in talent development; thus, inquiry that sheds light on these issues would be beneficial as well. With this is in mind, three overarching research questions drive this study:

1. How do STEM administrators, faculty, program directors, and pioneers in STEM (i.e. nationally recognized faculty and administrators who have dedicated their careers to groups traditionally underrepresented in STEM) identify student talent?
2. How do these institutional agents position undergraduate students for STEM success?
3. What institutional resources or policies support faculty in cultivating STEM student talent?

This paper will help STEM educators and other institutional leaders understand why it is necessary to adopt a talent development approach toward STEM education wherein a broader range of competencies and performances are assessed and students receive recognition for their progress. Within this research, we offer insights in terms of how to direct efforts to better support STEM students—especially URMs—as they acquire and develop knowledge, skills, and abilities that allow them to pursue STEM-related careers.

Literature Review

Perspectives on Talent

There are different perspectives within the literature related to the origins of talent. On one end of the belief spectrum, are those who believe talent is a product of innate traits, wherein a person is born either having a propensity to excel in a subject area, or not. On the other end are those who believe that talent is mediated by contextual factors (Richards, 2015) with sociocultural factors (i.e. family influence, teacher expertise, and early exposure to teaching) and deliberate practice influencing cognitive abilities (Vygotsky, 1978; Howe, Davidson, & Sloboda 1998). In other words, talent grows via a variety of nurturing learning experiences acquired from the environment (Dai, 2009; Dai & Coleman, 2005). At the far end of the belief continuum, some contend that through deliberate and arduous practice, all individuals are able to master almost any skill (Simonton, 2001). From this perspective, talent is a fluid quality rather than static, with anyone having the potential to achieve success in higher education (Plucker & Barab, 2005; Cliff & Hanslo, 2009).This view of talent is by far the most inclusive as an emphasis is placed on developing and cultivating an individual's potential along a continuum (Richards, 2015; Morelock, 1996). In the psychology literature, lay or implicit theories regarding the formation of intelligence and talent have been studied empirically as being fixed (innate) or growth (malleable) mindsets that affect motivation and behavior (Dweck, 1999; 2008).

At the midpoint of the spectrum of talent perspectives are those believing that talent is a mixture of innate traits and acquired abilities that interact with each other, although it is unclear which factors dominate (Lidor, Côté, & Hackfort 2009). The Differentiated Model of Giftedness and Talent as proposed by Gagné (2004), accounts for the interplay between nature and nurture factors in talent development. Specifically, Gagné's purports that talent is a developmental process influenced by several factors including ones that are environmental (e.g. access to learning resources, the influence of key individuals in a student's immediate environment) and "chance" (e.g. socioeconomic status, quality of parenting) (Gagné, 2004; Richards, 2015). Indeed, the majority of research contends that talent encompasses elements that are both innate and acquired; however, it is difficult to discern which aspects of talent can be cultivated via environmental interventions and which are difficult to change and therefore more innate (Walker, Nordin-Bates, & Redding, 2010).

It is important to note, however, that social factors are not typically due to “chance” but are part of the reproduction of social inequality, and have much to do with resources and accumulation of social advantage in academic and work settings. For example, research on the career trajectories of scientists demonstrates a pattern of growing inequality with respect to productivity, recognition, and performance, as early career success attracts new resources and rewards that promote continued high levels of achievement (Allison, Long, & Krause, 1982; Allison & Stewart, 1974). Therefore, it takes institutional agents in the campus environment to identify and cultivate potential at early stages among those students that are not bequeathed with initial advantage in terms of resources that impact academic achievement.

Approaches to Identifying Talent

Moving from a discussion of the origins of talent, to a discussion of how talent is identified, recent studies often measure talent by utilizing “superior performance” as a proxy, which is the demonstration that an individual is performing at the highest standards of some objective measure of intelligence (Dai, 2009). As applied to institutions of higher education, superior performance would be measured by earning an ‘A’ grade on all assignments and tests in a STEM course. Another approach to identifying talent not so much used in the United States but commonly used by UK government initiatives, is to evaluate students on the basis of future potential rather than existing skills alone, “thus allowing for the identification of untrained but potentially gifted students” (Walker, Nordin-Bates, & Redding, 2010, p. 167). Notably, just because someone demonstrates intelligence in one area, does not necessarily translate to intelligence in another (Sanders, 2006). Indeed, talent is a multidimensional concept (Walker, Nordin-Bates, & Redding, 2010), with no single factor alone being an indicator of talent. Further there are many skills that simply cannot be observed by an evaluator.

Since we are primarily concerned with the talent development of diverse students, a consideration of the cultural values, norms, and behavioral expectations specific to STEM disciplines is necessary in discussions of talent (Weidman et al., 2001). Indeed, students gain knowledge and competence in their respective STEM fields within a normative structure of participation, which is reflective of the value system and interactional behaviors of majority members. Because STEM as a field is historically and currently dominated by the presence of white men, the dominant narrative regarding what talent looks like in practice is based on white male norms and has a powerful effect on how students are evaluated both by peers and by faculty (Antony, 2002). One norm common in STEM culture is a survival of the fittest mentality, which prioritizes the individual interests above the group and promotes competition over collaboration (Seymour & Hewitt, 1997). Students who exhibit behaviors that do not align with the dominant academic culture or who are not willing or able (given their interests, values, and skills) to work with the existing structure and rules will presumably be judged as having less talent or lack of interest (Johnson, 2007; Tate & Linn, 2005). Because talent identification and development go together, the lack of consensus on what talent is and how to cultivate it has major implications for teaching practices and inclusivity in STEM classrooms (Howe et al., 1998; Richards, 2015).

The Role of Institutional Agents

To understand the role of faculty, program directors, administrators, and pioneers in cultivating the talents of students, particularly among underrepresented racial minority students from working-class or disenfranchised urban communities, and positioning them for success in STEM majors, we draw on the concept of institutional agents proposed by Stanton-Salazar (2011). Institutional agents are “high-status, non-kin, agents who occupy relatively high positions in the multiple dimensional stratification system, and who are well positioned to provide key forms of social and institutional support” (Stanton-Salazar, 2011, p. 1066). The notion of institutional agents recognizes two important points: first, social stratification exists in educational structures along hierarchies of class, race, and gender. Second, low status youth have differential access to resources and experiences that increase engagement and academic achievement within post-secondary educational spaces (Stanton-Salazar, 2011).

As follows, individuals within an organizational structure act as institutional agents when they intentionally provide key, highly valued institutional resources, forms of support, and opportunities that authentically empower traditionally low-status students in their social development and educational attainment. Institutional agents, via their relationships with students, help students learn how to negotiate and participate in the sociocultural world of STEM disciplines, which in turn translates to increased access to an assortment of social and institutional resources, privileges and rewards, which include academic support, advice, and guidance (Stanton-Salazar, 2011).

Organizational Capacity to Cultivate Talent

Psychologists have broadened their work to include identification of implicit theories of intelligence embedded in institutional contexts. Murphy and Dweck (2009) refer to an organization's theory of intelligence, which refers to "the shared beliefs of people within a setting that intelligence is either a fixed and stable trait or a malleable and expandable quality" (p. 1). Their empirical work demonstrated that when theories of intelligence characterize and organize a setting, they shape people's cognition, affect, and behavior in important ways that conform with organizational normative views about talent. The success or failure of institutions in facilitating minority achievement in STEM majors at the undergraduate level is suggestive of how institutional agents view talent for scientific work. HBCUs, for example, are generally known for their ability to produce STEM degrees among Black students at the undergraduate level (Joseph, 2013; Stage et al., 2013; Hurtado et al., 2008; Perna et al., 2009; Seymour & Hewitt, 1997). This success is attributed to their ability to provide a safe and affirming educational environment in which students are put first, held to high expectations, and given the support and encouragement they need to succeed (Hrabowski, 2013). Indeed compared to faculty at PWIs, faculty at HBCUs tend to demonstrate a greater dedication to teaching and have a firm confidence in their students' abilities (Fries-Britt, Burt, & Franklin, 2012).

To increase their capacity to produce STEM bachelor's degrees among URM students and make the shift from sorting talent to cultivating talent, institutions will have to consider making a variety of changes, as demonstrated by the successful institutional transformation of the predominantly-white campus, University of Maryland, Baltimore County (UMBC). The UMBC leadership team has successfully cultivated an academic culture of "inclusive excellence" wherein the achievement of minorities in STEM is now on par with their non-URM counterparts also pursuing STEM majors. As the leader in chief of his institution, the UMBC president highlighted the need for change by using institutional data on the achievement of minority students' in STEM during his dialogues with the campus community (Maton et al., 2008).

In talking about enhancing the achievement of minority students in STEM, Maton, Hrabowski, and colleagues (2008) outlined the key strategies the UMBC leadership team – which included the president, other senior administrators, chairs of various STEM departments, and interested faculty – used to ensure the success of change efforts. First, the leadership team held a shared and committed vision, and spoke about that vision inspirationally to the larger campus community to prompt buy-in. They also mobilized resources from grants and then leveraged those resources. Other strategies the UMBC leadership team used included developing and clearly articulating the institutional goals that were to be reached; explicitly showing how these goals aligned with institutional values and priorities; strategically planning how changes were to be made inclusive of incentives and rewards that were to be used to change the behavior on campus; and constantly evaluating implemented strategies to allow room to modify action based on lessons learned. Finally, coalitions were formed across the campus of interested faculty, staff, and administration to ensure that there were pockets of people in different parts of campus continuously driving change efforts (Maton et al., 2008) to reach inclusive excellence in STEM productivity. While the UMBC example is widely known, we empirically selected several institutional exemplars in STEM degree productivity to understand overall campus patterns that support student talent development and the institutional agents that advance this approach. Case study methods enabled us to identify other characteristics of individuals within institutions that contribute to higher STEM degree productivity, as detailed in the next section.

METHOD

This paper brings together data from three qualitative studies to examine themes of talent identification and development within post-secondary education. The first was a study of STEM introductory classrooms and is comprised of eight institutions, at which we conducted interviews and focus groups with faculty. The aim of data collection was to uncover the unique strategies and pedagogical practices in introductory science and math courses that lead to successful development of the skills and dispositions necessary for continuation through the college pipeline. We defined an introductory course as the first course in a sequence of courses where knowledge is cumulative. Faculty interviews ranged from 60 to 90 minutes long. Participating faculty members taught introductory courses in various disciplines including chemistry (n=10), biology (n=9), mathematics (n=5), physics (n=1), and engineering (n=1). Teaching experience ranged from two to 40 years. The institutions included one Hispanic-Serving Institution (HSI), one Historically Black College or University (HBCU), and six predominantly White institutions (PWI). Institutional control divided evenly between public and private institutions.

The second qualitative dataset is comprised of case studies from six institutions that represent diverse institutional types and that have had exemplary success in producing underrepresented racial minority college graduates in STEM majors. We relied upon the efficiency scores generated by stochastic frontier analysis to select ‘exemplar’ campuses for inquiry. To do so, we used degree completion data from IPEDS averaged over several years (i.e, 2002, 2004, 2006, 2008, 2010, and 2012) and accounted for the human capital, financial capital, and labor resources available at each institution as they are important considerations in the degree production process. Our approach is unique in that it identifies campuses that are having great success with respect to STEM bachelor's degree production, taking into account resource differences across campuses. We also considered status as a minority serving institution or not, the number of URM students enrolled (so as to avoid campuses that had high efficiency scores but enrolled just a handful of URM students), geographic diversity, variation in selectivity, availability of intervention programs (e.g., HHMI funding, MARC, MBRS, IMSD), stability of leadership (i.e., avoiding campuses undergoing transitions in top-level administration), and variability in institutional control. After considering institutions with top efficiency scores for Black, Latino, and Native American students in STEM, we ultimately selected six institutions: an HBCU, an Indian-serving institution, and two Hispanic-serving Institutions, and two highly selective and predominantly-White institutions (one large and one small). The multi-institutional analysis allows for validation of the findings across sites, and multiple interviews per campus allows for cross-validation of findings within institutions (Yin, 2013). To explore the institutional context for students, 20-25 STEM faculty, program directors, and administrators were interviewed at each of the six campuses.

The third qualitative data set involved interviews with STEM "pioneers" who have worked throughout their career on improving outcomes for women and URMs. Purposeful sampling was used in order to generate information rich cases about their careers and efforts to improve diversity in STEM fields (Patton, 2002). Participants were selected based on longevity and success in their field, national recognition, and evidence of a long-term commitment to diversifying STEM. Each were identified through professional organizations (e.g. SACNAS), website lists, and lists that contained the names of people who won awards from such organizations. Biographical statements were developed and a final selection was based on race, gender, and disciplinary training. This resulted in 32 senior level pioneers, nine of whom were in biomedical/behavioral sciences, 12 from physical sciences/engineering, and 11 program administrators from these disciplines. The diverse group included 50% women, nine Black, 14 Latina/o, three American Indian, four white, one biracial, and one African. Each was interviewed in person or on the phone by a member of the research team.

Data Coding and Analysis

In developing the coding architecture for the three datasets, our team of four to six researchers (depending on the dataset) open coded each transcript by examining the raw data and coding for salient themes supported by the text (Corbin & Strauss, 2014). We used a constant comparative approach following an inductive process of narrowing from particular (text segments) to larger themes while allowing the researcher to attempt "to 'saturate' the categories—to look for instances that represent the category and to continue looking... until the new information does not provide further insight into the category" (Creswell, 2013, p. 195). We then developed axial codes by narrowing larger text segments to interconnected themes and categories (Corbin & Strauss, 2014). Our team of researchers each read the transcripts of individuals at different institutions, gathering and comparing themes across focus groups/interviews and institutions, which also enabled analytical triangulation (Patton, 2002). Once we determined that we had reached saturation in generating themes, we developed several iterations of coding schemes, wherein codes were created, expanded, defined, and refined. Following inter-coder reliability exercises where we reached 80-85% agreement, the coding was revalidated and new codes and sub-codes were added as necessary (Miles & Huberman, 1994).

In order to address the stated research purposes, we used qualitative software to run queries and to test hypotheses in the data based on our guiding theoretical framework and literature review. In order to move beyond simple reporting of thematic codes, excel spreadsheets were used to visually display the data. This method allowed the researchers to systematically "see" the data and to view it in one place via the use of columns and rows (Miles & Huberman, 1994). In this way the researchers were able to draw more valid conclusions by comparing categories of information (i.e. the codes) in relationship to each other (Bair & Haworth, 2004). The use of matrices not only helped determine how codes related to each other, but was also a good method to use to make contrasts and comparisons between institutions (Miles & Huberman, 1994).

Findings

Defining Talent

There are multiple ways in which STEM faculty identify talent among students. Some professors admitted to using a curve so that grades were normally distributed and to account for an expectantly easy or difficult test as measured by the percentage of students who pass, but which clearly does not account for student learning and development during the term:

> Yes, I use a curve. Otherwise based on my tests, everybody would fail my class. *[Laughter]* …The way I determine grades is at the beginning of the quarter there's a syllabus which is essentially a contract. I spell out exactly this percentage will be based on homework, this percentage will be based on midterms, this percentage will be based on your finals. Well, I had one test, and I'm so embarrassed, where students did too well… Once I saw that, I knew I could really ration up the difficulty of the remaining tests… What I try to do is I put in a variety of questions. Some are very easy, some are very straight forward, some medium difficulty, there's a twist, some very, very challenging. Then when I have that kind of a test, the scores are fairly nice and distributed… I draw a histogram and then I look for bumps, 'cause people clump together. I'm very excited when I can get a couple of good bumps. Usually the big bump in the middle is the B's. Then I work out from the bumps from there… I like the flexibility of saying my grade is curved. – *Mathematics Professor, Introductory Classroom Data*

Other participants also acknowledged that some colleagues in their respective departments use grades and test scores as indicators of talent. Many participants saw this definition of talent as being both narrow and restrictive as it traditionally only allowed for a few stellar students to rise to the top, especially in classes where grades are allocated on a curve. Curved grades are limited in that they don't indicate level of content mastery, as one Biology Professor (Introductory classroom) stated, "Every instructor will say this is exactly what's expected of you [then grade on a curve]...I think that it's unfair. I think we have no idea what [students] know when they leave."

To some participants, curved grades are especially problematic, because curves position students to be in competition with each other, which they explained is detrimental to reciprocal peer learning:

> No, I don't believe in grading on a curve. There's one professor I know that does and I totally disagree with that. I don't believe in making it so competitive that it doesn't matter what you made, it just matters where you landed. I don't agree with that at all. I tell [students], "If you all earn an A, I will very gladly write down an A for every single person. On the other hand, if you all make an F, I will write down an F for every single person." It's funny how they smile at the A, and then when I say the F part, they're like, "You can't do that." [Laughter] I've never had to, but I don't grade on a scale or a curve. – *Statistics Professor, Introductory Classroom*

Other STEM faculty shared that they use grades as proxies for students' work ethic, attention to detail, or passion regarding the course topic. To these professors, students who do not get high grades in their classes, are not necessarily lacking talent or intelligence, but simply are not putting in the time and effort necessary to perform well:

> I don't need the curve anymore. Students…will get their exams back with numbers (i.e. grades) on them that they don't like and they will say, '[Professor Jones] are you going to curve this?' And I will say, 'No, because you have got all kinds of opportunities outside of your exams to earn points for this course. And as I said at the beginning of the class, 45 percent of the points in this course are really just based on work ethic, not on exams.' So I will just tell them I don't feel badly about having that policy. It is your job to control your college career. – *Chemistry Professor, Introductory Classroom Data*

Some STEM professors use grades to track students' progress and development over the duration of a course:

> I follow the students through the semester in terms of how they have been improving. Let's say I start with somebody that made a 50 on my first exam, but then that person ends up with an 80 something on the last exam, so you see progress. You see that the person has not given up. You see that the person is actually working hard. – *Chemistry Lecturer, Introductory Classroom Data*

In contrast, the vast majority of interview participants held far broader definitions of talent wherein standard academic achievement indicators (i.e. grades, test scores) were seldom used to identify "talented" students. Instead many faculty and pioneers to whom we spoke conceptualized talent as a fluid, developmental characteristic that most students can possess, with different types of talents being necessary to be successful in the classroom or the lab ("doing science"). As faculty shared, talent was not merely about mastering scientific content, but possessing some of the behavioral characteristics that make for a successful STEM professional in one's field. From this standpoint, having talent is to be a leader, have an inquisitive mind, think and ask questions that are outside the box, and be comfortable with ambiguous problems. By definition, more students are able to demonstrate these behaviors and therefore demonstrate talent. Most importantly, the broadest definition of talent communicated by faculty was the quality of being excited to "do" science, being persistent in the face of challenges, using existing knowledge to mentor others, and desiring to use science as a means to improve society. Having the potential for talent is also indicated by being open to learning, challenging oneself, and taking chances. As a full professor in chemistry and director of a research program for STEM students explained, talented students are:

> The ones that are risk takers, the ones that are willing to fall down and pick themselves up again, the ones who aren't afraid of making a fool of themselves, of looking at things differently… they have to be open to learning as opposed to [simply] memorizing and getting good grades... It's people who like puzzles and who don't mind being wrong, who know that there's a bigger payoff farther down the road. – *Pioneer Data*

In short, from this perspective, talent does not mean much if a student does not have a passion for science, lacks work ethic, or is not willing to put in the time to learn. Further, a demonstration of scientific competencies is diminished if students are hindered by poor grades or setbacks in the lab. Alternatively, a student can be struggling to get high grades, yet still be viewed as talented:

> You can tell when somebody has a spark at being able to think about a problem in a way that's different from other students. Being good in mathematics -- that helps and it'll show up in the grades. But not always is it the case that somebody that's performing at a very high level in math class is going to do creative work in the lab. Sometimes I've been surprised. I'll recruit somebody that I think is going to be awesome that ends up not being that interested in doing stuff in the lab. And vice versa, I'll recruit somebody that maybe didn't do so well in the course, but I can tell has interest and is creative. – *Mathematics Professor, Exemplar Institution*

Faculty often hired past students, who sometimes did not receive the highest grades, to help them in a current class as learning assistants because these students had to work diligently to perform well in the class. Communication skills were also a major consideration when asking students to be learning assistants:

> I, at least, consider success to be on some of the areas that cannot be assessed as easily. The interaction within the group, interpersonal relation skills, communication skills… If I'm looking to identify a student who would do well as [an assistant] to help with one of these courses in the future…we go beyond just performance in the class. In fact, in some cases the A student is not the best person to help out in the classroom. Sometimes it's good to get a B level student who is good with the content, but also recognizes what it's like to struggle and can relate better to those who are struggling. Because physics is not easy. Students at all levels will struggle with it at some point. And being able to relate to other people in that process is important. Scientists aren't always known for their interpersonal relations skills. Being able to identify that talent and ability in both the content area and then also the soft skills, people skills, is important too. – *Physics Professor, Exemplar Institution*

Notably, a handful of faculty who held broad definitions of talent also acknowledged that the scientific enterprise needed to be diversified across lines of race and gender; they therefore saw the use of active learning pedagogy as practice that was in alignment with social justice imperatives because it was more inclusive of people from backgrounds typically excluded from science:

> I really was motivated to make a difference in terms of our underrepresented minorities… I had gotten some data that suggested there was a big achievement gap for our black students in my class… So it just really hit me deeply [because] I know these students come in [from] different places. But I just felt like maybe I could do something to help them all get to a more similar place [with respect to content knowledge] in my class. So I really let go some content, not a lot, I kept my expectations high and like I said I just really keep a lot of structure to my class.

> As I get more and more experience [with active learning], I do a much better job with metacognition and inclusiveness… We looked at some survey data and… also found out that there was a participation gap, so our underrepresented minority students didn't feel comfortable participating in the big traditional classroom. But when they get a chance to just talk to neighbors [in small working groups], there is no longer a reason that they wouldn't participate. – *Biology Instructor, Exemplar Institution*

In alignment with this view, anyone who was genuinely interested in and passionate about participating in the STEM enterprise needed to be supported to acquire greater skills and to reach their full potential. This may explain why faculty who hold a broader conception of talent seem to more frequently rely on the use of hands-on, collaborative group activities in the classroom as a method of teaching.

Several faculty also discussed the challenges of identifying talent, particularly in large, introductory courses because they wanted to avoid completely relying on test grades to sort students. As one Chemistry professor shared:

> I made more of an effort this year...to sit down with the students, to get a really good sense of them. You can easily tell if a student is engaged about the learning or whether maybe they're just a good test taker. ─ *Introductory Classroom Data*

Indeed, getting to know students on a deeper level to determine students' aptitudes for scientific work was a better gage of talent.

Cultivating Talent for STEM Success

Cultivating talent means helping students reach the peak of their potential as student scholars and as future professionals in STEM. Talent is cultivated within institutions at the individual, classroom, and program levels.

The individual level. At the individual level, pioneers and faculty at exemplar institutions cultivate talent by granting students access to opportunities they would not have otherwise, by providing a level of psychological/emotional support to students, and by offering guidance for future steps. With respect to access to opportunities, faculty put students in their labs that they believe have the potential for talent, hoping that the research will further excite them; at times, faculty publish with their students. Some faculty purposefully target research opportunities to those who they feel need the research to remain in the sciences and who can blossom with proper mentorship. Some professors however are concerned with overburdening students who are not performing academically well, with the additional responsibilities of research. As a professor of Biological Sciences from an exemplar institution shared, “If they have three A’s and a B per semester that’s a sign that they’ve got their academics down and they can take on new responsibilities without it harming their academics.” Once in the lab faculty cultivate talent by introducing student researchers to a network of people within the institution, and sometimes STEM professionals in industry, who the faculty know can provide additional guidance and mentorship to students.

Cultivating talent required that faculty provide students with some level of psychological/emotional support. STEM faculty described talking to their students, taking an interest in their interests, and motivating students based on their interests. As young scientists, students tended to doubt their own abilities and needed reassurance in the face of setbacks. Not only do faculty validate and affirm students’ place in the STEM classroom and lab, but faculty also repeatedly remind students’ that they can be successful in a STEM major and the STEM workforce. Indeed, faculty play an active role in recruiting students into STEM disciplines.

> If I recognize that I have a strong chemistry major, I’m going to try to place them in a laboratory to immediately get the experience. I will contact this individual and I will tell them, “I would like you to come to me. Once you’re done with organic [chemistry], let’s see if we can place you in a lab if I can actually find somebody that will meet with you, will interview you and will try to give you a chance to get some research going on. ─ *Chemistry Lecturer, Introductory Classroom Data*

By directing students into meaningful STEM experiences, when they would have never considered a STEM pathway, faculty expand the pool of STEM talent.

Sometimes faculty were also responsive to students’ backgrounds and circumstances to help determine how to best reach students and cultivate their potential for talent. Specifically, faculty were understanding and accommodating of life events that stood in the way of achievement:

> I just see how many obstacles a lot of our students have to overcome. And…college was so easy for me thinking back. I didn't have to work 40 hours a week. I didn't have to take care of my grandmother or go home and still have to cook for my family and take care of my younger siblings…there are so many physical and also emotional, psychological obstacles that our students face. And I'm usually, really, really impressed and inspired by [my students] -- that they're still here. They can overcome so much and still be so upbeat, so positive and try so hard and still do so well in school. And so, it's not really [them lacking] talent. – *Professor in Chemical and Materials Engineering, Exemplar Institution*

Some professors are also very aware of their role as an institutional agent:

> The encouragement has to come from the instructor, and [students] have to sense that the instructor really and truly is interested, not just in the subject matter, but in the student. There has to be a personal connection. Some of us [STEM faculty] like to think that it's strictly just the science. No, you're dealing with a human being with real feelings. So you have to speak to [students] both at the professional and the personal level about the science that you're doing. It has to relate to them personally. — *Astronomy Professor, Pioneer Data*

Taking it a step further, there were several faculty that acknowledged that simply knowing pedagogical theory and best practices in teaching would fall short if faculty did not also understand how issues of diversity and identity played out in the classroom. As one exceptional STEM lecturer stated, "It comes down to being human."

With respect to the provision of guidance, most faculty wanted to best position their students for success either in a STEM career or in graduate school. Positioning students for success meant talking to students about their futures and helping them see that graduate school and an eventual career in STEM are both within their grasps. To help students plan for their futures, faculty were active in helping students identify graduate advisors at other institutions who would provide appropriate guidance to students in graduate school and who would engage them in research. Beyond providing advice, faculty actively wrote letters of recommendation for students with whom they had relationships, thereby acting as gatekeepers to greater opportunities in graduate school or the workforce.

Identifying students as peer learning assistants and for tutoring positions is also a way to both cultivate and reward talent. As one professor shared, these positions are a way to:

> Draw [students] into this inner circle where they step behind the curtain, and think more about how the course is structured, how to communicate the material.... the people that benefit the most [from this experience] are the [peer] leaders. – *Chemistry Professor, Introductory Classroom Data*

Interestingly, cultivating talent on an individual level necessarily includes mentoring as explained by a physics emeritus professor:

> Mentoring plays a big role in how the students feel about themselves. The ones that are properly mentored get to recognize, get to self-evaluate in such a way that they know where they should be positioning themselves. They know what level their talent is and therefore can make successful career decisions based on a proper evaluation of their situation. – *Pioneer Data*

The classroom level. Faculty cultivate talent at the classroom level primarily via their teaching and by signaling their approachability to students within their courses. Cultivating talent in the classroom is done by experimenting with a variety of innovative instructional pedagogies and course formats (e.g. team-based teaching, flipped classrooms, service-learning). STEM faculty shared a belief that these teaching methods promote active learning and learning that went beyond the mastery of course concepts and rote memorization. Teaching strategies that best promoted learning and helped students develop a growing interest in the STEM disciplines seemed to take on an engaging, talent development approach wherein faculty encouraged students to ask questions in class, provided hands-on learning experiences, and gave students assignments that required them to solve meaningful problems. By giving students the opportunity to excel in class via engagement in a variety of in- and out-of-class assignments, such as solving problems, leading others, and completing small research projects, faculty were more inclusive of a variety of abilities and showed that an array of talents that students already possess are valued. In other words, the approach is that every student has something to contribute. Taking an active role in the learning of students as a means to cultivate talent is necessary as explained by a mathematics full professor:

> I find unless I take an active role in their learning, [students] are not going to learn much. So in my math classes, for example, I give almost daily quizzes – very short, easy quizzes, but [it forces] the students to study until the last class, and work on the problems I assigned to them. [If they do what I ask of them], they should do very well on those quizzes. – *Pioneer Data*

Holding high expectations, according to faculty, helps students take ownership of their learning. Part of empowering students meant that faculty sometimes had to give quick lessons on how to efficiently study course content. Other times, flexibility was key in delivering course lessons:

> Well, I've been teaching for 18 years now and a lot of it is just being in the classroom and getting a sense for what works. Kids are just different [today] and so to ignore that means you're not dealing with reality. It's very important not to reduce the rigor, but certainly to approach things differently and grasp at anything that helps engage them and helps them become more active in the learning process. – *Biology Professor, Introductory Classroom Data*

Impressively, several faculty members shared that they were reflective about the pre-college educational backgrounds of their students. One instructor of a large introductory biology class explained that she actively strives to help her students adopt a growth mindset. In an attempt to level the playing field, she reminds students that if takes them “two hours or two days to complete an assignment,” they should all take comfort in knowing that by doing the homework, they all come to class with roughly the same level of expertise on the content being covered. Further, a few faculty actively thought about how their teaching practices contribute to the learning and academic success of students taking their classes:

> The first and most important lesson I’ve learned is to appreciate the difficulty that some students have with the material and to make sure that they don’t feel judged for the difficulty that they’re having, to express the idea that some of this material is challenging, it is different from anything that they’ve had before. Some of it is not intuitive, and that’s okay. It’s okay to struggle with it, and many people do. They won’t be judged harshly for not getting it right away. – *Professor in Ecology and Evolutionary Biology, Introductory Classroom Data*

The pedagogical practices of faculty in the classroom are not the only means by which faculty cultivate their students' talents for STEM competencies. Many faculty recognize the value of being approachable to students. Many faculty shared that their students looked up to them and realize that harsh, overly critical feedback can be crushing to a student who is not yet confident in their skills, but nevertheless talented. Faculty also found ways to help students imagine themselves as STEM professionals by describing what STEM professionals in their respective fields do:

> I present what engineers do in an understandable way that makes it attractive. For instance, I don't get all involved in technology terms. Basically engineers are problem solvers who work on all kinds of problems that make life better for society—through solutions. Making life better for people is something that I think women [and minorities] relate to very much. That really is a lot of what engineering is about and it's a lot of what science is about. ─ *Dean of Engineering, Pioneer Data*

The program level. Intervention programs are focused on the identification and development of talent, providing what students need rather than leaving it to chance in the classroom or connections with colleagues. Directors of STEM programs work to maintain momentum in the cultivation of talent by institutionalizing their intervention programs. Such programs offer academic and social support, research or internship opportunities, and/or targeted scholarships to students majoring in STEM disciplines. Program directors shared that because of budgetary constraints, institutionalizing their programs takes a bit of hustle as they have to constantly be actively invested in fundraising efforts to create program endowments. Directors were proactive about reminding administrators that they have a responsibility to help students; administrators could serve this responsibility well by funding STEM intervention programs that begin as grant-funded activities. One particularly savvy program director, a full professor in mathematics, received continuous financial commitment from the state for intervention programs via pushing for the passage of a bill on STEM training.

Program directors are also concerned about the leadership of their programs and ensuring that there is always a group of individuals who are ready to carry out the mission of the program, who share the values that the program espouses, and who can lead the program to new frontiers. By partnering with other faculty who deeply care about student success in STEM, showing these faculty members how the program runs, and giving these individuals leadership responsibilities while the director is still in office, program directors ensure the longevity of their programs. Further, having an excellent program staff who support the new leadership, will ensure a seamless process between one director and another. Finally, having more than one person on the leadership team of a program that shares a growth mindset and views their role as an institutional agent ensures that any one person does not experience burn-out out and that the leadership is always at its best.

Institutional Resources or Policies that Support Faculty in Cultivating Talent

High level administrators do their part to support STEM talent by channeling money to buy the technology needed to implement novel teaching strategies, by providing funding to expand or start interventions that work, by creating faculty incentives for excellence in teaching and mentoring, and by applying to grants and engaging in fundraising efforts to support faculty in their work with students. Administrators also supported the cultivation of talents by intentionally hiring exceptional faculty who enjoy teaching and partnering with students for research:

> I hired nine-tenths of the faculty. Most of the faculty that I hired are still there, and they're still interested in the same thing. I changed the culture, and so… when someone would come in to interview, I told them, "This is what I expect," [and] they would find out from the other faculty. ― *Dean of College of Arts and Sciences, Pioneer Data*

Indeed, institutions that do exceptionally well in cultivating students' talents communicate high expectations for teaching during the interview/hiring process, and in this way slowly begin to create change at a broader level. Similarly, administrators use their position to incentivize faculty to engage in better teaching and mentoring of students:

> I made that part of a requirement for what I expected faculty to do in order to get merit raises or to get promoted--they needed to involve students in their research… I don't think they believed me until a few faculty started doing it, and they got high raises. Then that convinced everybody else that they should behave in the same way. It provided the incentive to make that cultural change, not because necessarily they believed in it, but I very strongly believe that you don't have to believe what I want you to believe; you just have to behave right. – *Dean of College of Arts and Sciences, Pioneer Data*

To be most effective in reinforcing the cultivation of students' talents, incentives, policies, and practices had to come from multiple offices on campus and address multiple audiences:

> One of the things that I pushed throughout [my career] was that we have to get this from many different levels. We have to train junior faculty. We have to try to implicate senior faculty. We have to train the next generation of post-docs and graduate students. We have to provide grant incentives. We have to provide awards. We have to provide negative reinforcement for the other ways [that reduce STEM success]. Just in every angle, I see different ways of either rewarding or discouraging the behaviors we either want or don't want respectively. – Biology Professor*, Pioneer Data*

At a few institutions, however, getting funds to attend a teaching conference was a bit more difficult due to severely tight budgets. In these cases, faculty had to make the case that professional development funds would be used for a beneficial cause and later showcase how those funds were improving outcomes among students. Only in a handful of cases did faculty have to convince administration of the benefits of teaching that promoted active learning.

Faculty and instructor lines. Across most of the exemplar institutions, there was a big push from upper administration and department chairs for faculty to better cultivate the talents of students. The Provost and/or Dean's offices at a few institutions committed resources in areas thought to be instrumental in facilitating reform in STEM education, particularly at the introductory level of core STEM courses. Two types of faculty lines seem to help with course reformation and pedagogical innovation. The first faculty line was for hiring tenured-track researchers in STEM education in specific departments. Notably, this was a research position, not an instructional one. A Chair for the same institution wherein STEM education faculty were hired explained:

> So by hiring one of these [STEM education researchers], I am hoping that they will help us to think about [discipline specific] pedagogy [and] the way we teach. It's not their job to fix all of our classes, but to spark...new conversations into the department. – *Chair and Professor of Chemistry*

To cultivate students' talents, institutions also focused on the hiring and strategic use of STEM lecturers, rather than temporary adjuncts. STEM lecturers are talented fixed-term, full-time teaching faculty who have deep knowledge of the literature around discipline-based education, learning, assessment, and cognition in STEM disciplines. The institution that employed STEM lecturers gave them a lighter teaching load compared to other adjuncts because STEM lecturers were expected to lead a master-apprentice program and a peer observation program. Within the master apprentice program, STEM lecturers provide intensive training to faculty who are enthusiastically interested in course redesign and active learning pedagogy. Indeed, lecturers act as the master teacher, with senior and tenure-track faculty apprenticing themselves to learning how to employ more effective teaching methods. Sometimes mentorship came in the form of the apprentice faculty member team teaching a class with the STEM lecturer.

With the peer observation program, STEM lecturers allow interested faculty to visit their classes to observe and learn how best practices in teaching occur in action. STEM lecturers can also, as requested, sit in on colleagues' classes to give teaching suggestions. Overall the hope is to encourage the idea that teaching is not private, that best practices in teaching are constantly changing but can be learned, and that infusing better teaching practices into one's classroom does not necessitate extensive training time. In short, it means using a growth mindset about teaching, which is sometimes thought to be an innate talent, and also embedding it in the culture of the institution.

Interestingly, to retain talented STEM lecturers, the administration gives STEM lecturers consistency in employment (contracts are between three and five years long) along with benefits. Administration also created a promotion process so that STEM lecturers can, pending evaluation, become senior lecturers, which comes with greater pay and stature. In fact, at this exemplar institution, STEM lecturers enjoy many of the privileges that tenure-track professors enjoy. They sit on committees, apply to grants with tenure-track faculty, are included in faculty meetings, and have access to professional development opportunities including stipends for conference travel. In this way, STEM lecturers are not just engaged in the classes they teach, but are also integral actors in the life of a department. The administration at another institution made a deliberate decision to avoid hiring part-time lecturers who would only teach one class to fill a gap in the teaching schedule, because the administration felt that lecturers needed to teach the same class multiple times to develop their craft.

Course releases and peer learning assistants. Campuses provided faculty with other resources to help them transform STEM education. As the chair and professor in Chemistry from an HSI institution shared, “I'd like to transform physical chemistry [but] quite frankly I don’t want to be asked to do it on my Saturday or by working 12 hours a day... Don’t ask me to do that. Give me some resources.” Fortunately, many administrators seem to recognize that making improvements to teaching and pedagogy are time intensive activities and that STEM faculty need a tremendous amount of support if they are expected to engage in professional development around teaching. To support faculty in improving their classes, administrators report leveraging the few “carrots” they have which include offering course releases to those interested in reforming their classes, stipends or summer salaries to those who attend an institute on teaching and use that knowledge to develop their courses, one-to-one teaching consultations for any faculty teaching classes with an enrollment of 100 students or larger, and lunch for people who opt to attend teaching workshops sponsored by the Teaching and Learning Center.

Notably the classes at every single exemplar institution we visited were growing due to fiscal pressures. Two especially useful resources in large classes are graduate student teaching assistants (TAs) and peer learning assistants (LAs). As the Director of the Learning Assistant Program explained:

> Learning Assistants are undergraduate students that are in class to facilitate learning. We train them for one semester they take pedagogy course that we call 'a seminar in science education.' And they are trained to help students learn. We always say the difference between a TA and an LA is that a Teaching Assistant will help the teacher. On the other hand, Learning Assistance help students. So we train them in understanding how people learn [and] the best ways to support students. – Program Director, Exemplar Institution

Hired assistants give students taking a given class additional attention that a single professor simply does not have time to give. LAs and TAs sometimes lead workshops to help students understand course content and some faculty reported how assistants helped improve student achievement. Despite having the help of TAs or LAs, many professors spoke about the challenges associated with teaching large lectures, even though they were creative in the techniques they used to get students involved. One Biology Professor from the Introductory Classroom Data explained, "When you're dealing with several hundred in one classroom, the things that you [are typically able to] do in the smaller class just become more unwieldy." Therefore, large classrooms continue to present problems in focusing on individual student talent development.

Teaching and learning centers. Teaching and Learning Centers seemed especially concerned with the development of professors teaching introductory core classes. As a Provost and Chief Academic Officer at an HBCU shared:

> We have a Center for Excellence in Teaching and Learning, which is a kind of one-stop-shop for all support for teaching…In the recent years, we've really been looking less at subject matter and more at teaching towards competency outcomes. So developing rubrics around critical thinking and quantitative literacy, scientific literacy and really helping faculty to look at syllabi and think about how they are presenting [content] and how they are assessing to ensure that they are assessing the competencies... So we try to use our Teaching and Learning Center to give [faculty] good feedback on…how you might in fact present this content in a way that is more accessible, that helps with deeper processing of the information. – *Exemplar Institution*

Teaching and Learning Centers sometimes facilitated faculty learning communities, which make learning about pedagogical innovations and course redesign a social endeavor wherein faculty learn from each other on an informal basis. Faculty in these learning communities talk about a variety of topics including: how to connect the course they teach to later, more advanced STEM courses; what they can do to help students feel more integrated in the classroom; how developmental stages in reasoning skills impact learning; the concepts driving learning goals; how assessment of learning goals will be measured; and the kind of feedback they are willing to provide students. In sum faculty in these learning communities:

> Share what works [and] what doesn't work. If they're seeing trends in what works with minority groups, underrepresented groups, they can share those with one another. So those learning groups are a key element to ensuring that if you're having success [in the classroom], you share it, and if you're having failure, you know who to talk to [and learn how] you might do better. – *Chair & Professor of Physics and Astronomy, Exemplar Institution*

Impressively, the Teaching and Learning Center at one institution also puts on an annual all-day professional development in teaching conference so that faculty across campus can showcase what works in terms of teaching. The Center also keeps track of attendance so that they can reach out to department chairs if no one from their respective department attends. Another institution has an entire day devoted to faculty development right after graduation and the entire faculty is required to go. This ensures the development of new expectations and a culture focused on improving teaching and learning.

Discussion and Conclusion

This study provides a better understanding of how institutions can organize their STEM learning environments to broaden participation in STEM and to develop the rich talents of a diverse population who will advance our nation's science-related goals and interests. By uncovering how exemplary campuses and institutional agents cultivate talent via their STEM programs and classroom practices, this study also helps other campuses that face inertia. Specifically, broad definitions of talent in educators' mindsets guarantee that a larger pool of students will be considered as having the potential to talk and think like scientists, and conduct science in ways that science is done. Talent, in the eyes of those we interviewed, is not simply demonstrated by having the best grades or scores on standardized tests. Nor is it something that is obvious at first glance. Rather, talent is expressed in a multitude of ways and is fluid rather than static (Plucker & Barab, 2005; Cliff & Hanslo, 2009). As follows, faculty who make efforts to get to know their students are more able to properly identify talent. Institutional agents identified talent as being characterized by persistence and effort, risk-taking, communication skills, passion, and creativity. More importantly, they viewed students who struggled with course content and overcame this difficulty as the type of individuals who could do science. This view of talent is much in line with a growth mindset (Dweck, 2008), rather than a fixed mindset wherein students give up if they do not believe learning STEM content will come easy to them. Indeed, talent is cultivated by giving students multiple opportunities for mastery, opportunities to explore pathways they may not have typically followed, and using techniques that allow students to demonstrate what they know and practice their emerging skills.

To be clear, even at exemplar institutions, we saw a broad spectrum of beliefs and views about student talent. Further, we did not see this same level of commitment or willingness to adopt a talent development approach across all STEM departments/disciplines. There was evidence, however, of an evolving culture change, supported at different levels of the institution that was already leading to new expectations and organizational norms regarding the cultivation of talent. Some institutions are starting to "meet students where they are" as part of a broader mission to most effectively advance the skills of the diverse students they serve. Faculty who could articulate this practice in their daily work showed how views about talent are embedded in the organizational context (Murphy & Dweck, 2009), and how such views can be reinforced in their environments. Institutions improve their capacity to improve student outcomes and apply a growth mindset to faculty work, when it is understood that STEM training activities are necessary and that good teaching is not a destination but a journey that improves with intentional practice. Talent development is also facilitated with the financial support given to programs, hiring and promotion practices, and expanded roles for institutional agents focused primarily on student learning in STEM disciplines.

A key contribution of the study is actual accounts about views of talent and how practices consistent with student talent development are changing in STEM. In the past, much of the burden of talent development was placed on the shoulders of program directors who led STEM interventions. There is now evidence, however, that talent development mindsets and behaviors can be diffused into introductory STEM classrooms. Further, this study demonstrates that a little faculty identification goes a long way in developing student talent. Institutional agents proactively reach out to students because students may not always approach faculty or recognize their own talents in STEM. Underrepresented STEM students, in particular, may not aggressively seek opportunities (even when they are alerted about them), especially if these students are not confident in their skills. By getting to know students' passions and capacity to work hard, faculty can build relationships to advance student talent.

Understandably, it would be unreasonable to expect faculty to give all the students taking their classes individualized attention. However, small acts of care and recognition matter. It can be as little as an encouraging note on an exam or, as one professor shared, "acknowledging that [students] exist, that they're visible to you, and… that you expect them to succeed." Indeed, many students may have only one faculty member in their entire academic career telling them that they are talented; that recognition, however, can help push students forward.

Cultivating talent does not stop with faculty. Upper level administrators support program directors and faculty in talent development activities. Indeed, the pioneers we interviewed and institutions we visited, demonstrate that a comprehensive, multi-prong approach is needed for the talent development of students – one intervention alone will not drive enough change. Administration can do their part by identifying resources such as incentives and awards for improved teaching and mentoring. Administrators can also support programs that cultivate talent and bolster student success by funneling money into these programs. Department chairs can provide negative reinforcement to discourage behaviors that are antithetical to STEM talent development. Faculty can train their graduate students and post-doctoral fellows with a mindset geared towards cultivating talent; this ensures that when these rising scholars become faculty themselves, they too hold such values. Further by mentoring students, faculty create a cadre of future ‘mentor-warriors’ in academia and industry who will push forward the talent development of the next generation of STEM scholars and professionals.

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