Cultivating STEM Talent: Lessons from Exemplar Institutions

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Abstract

This paper explores views of talent development among STEM faculty, program directors, and administrators from institutions that show success in producing STEM bachelor's degree graduates among institutions with comparable resources. We explored this theme across 11 high-producing STEM degree institutions in order to determine how institutional agents conceptualize and cultivate undergraduate student talent in STEM disciplines, and how institutional structures support and coordinate these efforts. Ways that institutional agents identify talent include observing academic skills, eagerness/zeal, thirst for knowledge, grit, and acuity. Institutional agents cultivated talent by engaging in multiple strategies to advance URM student' science socialization, network expansion, and access to material resources such as funding and scholarships. Implications for science education and training include broadening the pool of talented students via faculty mindsets and strategies as well as institutional rewards for faculty work.

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 understand how STEM faculty, program directors, and campus senior administrators identify and cultivate student talent, and how institutional structures and resources support undergraduate talent development in STEM disciplines. This work informs efforts in higher education to meet national goals of expanding and diversifying the scientific workforce (NAS, 2011).

Faculty and staff that operate as institutional agents to help students navigate and reach their potential 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 (Stanton-Salazar, 1997) in STEM disciplines. The provision of mentorship experiences (Borum & Walker, 2012; Johnson & Bozeman, 2012; Pfund, Byars-Winston, Branchaw, Hurtado, & Eagan, 2016), and the 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 institutional agents 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 produce numerous benefits to students pursuing STEM majors. While much of this work focuses on student performance, it also represents the outcomes of faculty efforts that include teaching, research training, mentorship, program leadership in departments, and initiative to develop specific interventions that address URM persistence and retention in science.

Therefore, faculty members' conceptions of scientific talent affect their investment in efforts such as mentorship and research with undergraduates. Narrow definitions of talent, traditionally measured by exam scores or course grades, likely influences the frequency by which faculty engage in these practices. Because mindsets regarding potential to develop talent affect behaviors of faculty and students (Dweck, 2008), particularly investment in students' learning and scientific training, it is important to understand faculty conceptions of student scientific talent. Definitions of talent that focus on a student's grades to identify their propensity for success ignore the reality that incoming college students have unequal access to quality K-12 education. Thus, focusing only on course grades fails to recognize students who have the potential to be productive professionals in the STEM workforce. Wider conceptions of scientific talent acknowledge students' diverse life experiences and capacity to rise above differential access to educational opportunities, or educational endowments (Johnson & Bozeman,2012).. Faculty that see the potential for growth in students are an integral part of URM student's science identity development that includes conceptions of competence, performance and opportunities to perform, and faculty recognition to be seen and see oneself as a scientist (Carlone & Johnson, 2007).

The students identified as having STEM talent are likely recipients of further investment including, but not limited to: 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. 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 an institutional agent recognizes talent in a student and seeks to develop it further. Those who are not identified as having exceptional talent may be left to rely on personal savvy and their own resources to survive in their undergraduate STEM programs.

In order for faculty to better facilitate the progression of aspiring STEM students to STEM degree completion and beyond, it is essential to understand how talent is viewed through a more expansive lens. Since faculty practices (i.e. teaching, mentoring, and coordinating intervention programs in the learning environment) 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 at institutions that are successful in producing STEM degrees, particularly among URM students. With this in mind, two research questions drive this study:

1. How do STEM faculty, STEM program directors, and senior administrators identify undergraduate student talent in STEM disciplines?
2. How do these institutional agents cultivate talent to position students for success in STEM disciplines?

By addressing these questions, this research 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 URM students—as they acquire and develop knowledge, skills, and abilities that allow them to pursue STEM-related careers.

Literature Review and Conceptual Framework

Perspectives on Talent

There are different perspectives related to the origins of talent. 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). 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 context (Richards, 2015) with socio-cultural factors (i.e. family influence, teacher expertise, early exposure to teaching) and deliberate practice influencing cognitive abilities (Vygotsky, 1978; Howe, Davidson, & Sloboda 1998). In other words, talent is developed via a variety of nurturing learning experiences acquired from the environment (Dai, 2009; Dai & Coleman, 2005). 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). At the far end of the continuum of malleable beliefs, 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 (Richards, 2015; Morelock, 1996).

Psychologists have also examined other individual traits that predict success. Apart from focusing on intellectual abilities to identify talent, the notion of grit, defined as “perseverance and passion for long-term goals” (Duckworth, Peterson, Matthews, & Kelly, 2007, p. 1087) has been examined as a predictor of retention and various success outcomes. Duckworth and colleagues propose that “achievement is the product of talent and effort, the latter a function of the intensity, direction, and duration of one’s exertions toward a goal” (Duckworth et al., 2007, p. 1098). Thus, a perspective on talent that ascribes to grit would place value on a student’s ability to stick with a difficult task, to demonstrate follow-through, and to stay focused on a long-term goal--such as obtaining a STEM degree and subsequently a STEM career. Although criticism has been raised that grit is not simply an internal psychological motivation construct but often neglects to acknowledge immediate effects of systemic inequalities like the daily slights that arise from poverty, racism, and sexism. This is particularly the case for underrepresented groups who face these additional obstacles on their way towards a STEM degree (Hurtado et al., 2009).

It is important to note that an individual’s perspective on what constitutes “talent” (fixed or innate, whether one prioritizes grit or not.) is also shaped by socio-cultural factors. For example, a faculty member who views talent as fixed or innate may have been socialized to rely on these measures due to the pervasive history of viewing these traits as necessarily for success in STEM. On the other hand, a faculty member who has been exposed to more malleable conceptions of talent, or who might relate to the challenges of being an underrepresented minority in STEM, is more likely to view talent as something that can be acquired through effort and support. Additionally, a student’s perceived “talent” by an administrator or faculty member is also socio-culturally shaped. In other words, a student’s observed traits and behaviors that signify talent 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 students' potential at early stages among those students who are not bequeathed with initial advantage in terms of resources that impact academic achievement.

Approaches to Identifying and Cultivating Talent

Moving from the origins of talent to 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). Applied to institutions of higher education, superior performance might be measured by earning an 'A' grade on all assignments and tests in a STEM course. Another approach to identifying talent 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). Apart from recognizing future potential, some recognize that talent is multi-faceted with no single factor alone being an indicator of talent (Walker et al., 2010) and that "talent identification and development should be considered together, rather than as separate processes, to allow for the selection of potentially gifted but untrained students" (Walker et al., 2010, p. 182).

These differing perspectives on talent is and how to cultivate it has major implications for teaching practices and inclusivity in STEM classrooms (Howe et al., 1998; Richards, 2015). 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). 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 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).

Building Asset Bundles to Cultivate Talent

To respond to the needs of students with minoritized social identities (i.e. race, ethnicity, gender, or economic status), Johnson & Bozeman (2012) propose an Asset Bundle Model that combines the scientific and technical human capital (STHC) model with social identity contingencies theory (SIC). Asset bundles are the specific sets of abilities and resources students develop to help them succeed in educational and professional tasks, such as science and research (Johnson & Bozeman, 2012). According to the authors, as the students' asset bundles develop, their insecurities and disadvantages stemming from status differences based on social identity will diminish. Thus, "by acknowledging the ways in which social identities shape students' experiences and development of assets (which we contend are directly related to educational outcomes), the Asset Bundle Model has the potential to help advance minority students through the scientific pipeline" (Johnson & Bozeman, 2012, p. 9). The assets to be developed include educational endowments, science socialization, network development, family expectations, and material resources. This study begins to provide empirical evidence from institutional agents that support elements of this model and other activities in cultivating talent among diverse STEM students.

Method

Data

The data are comprised of case studies from 11 institutions that represent diverse institutional types and that have had exemplary success in producing underrepresented racial minority (URM) 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. We developed efficiency scores for all four year institutions for All Students and scores for African American, Latinx, and Native American students. 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 11 institutions: two historically black colleges and universities (HBCUs), two institutions with high proportions of Native American students although they are not tribal colleges, four Hispanic-Serving Institutions (HSIs), and three highly selective and predominantly-White institutions (two 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, we interviewed between 9-35 STEM faculty, program directors, and administrators at each of the 11 campuses.

Table A1

Institutions in Study

Institution Pseudonym	**Control**	**MSI status**	**Classification**	**Efficiency Scores**	**Primary Role of Participants**
University of the Southeast	Public	N/A	Doctoral Universities: Highest Research Activity	82 Latinx .53 Black .35 American Indian	Faculty: 10 Staff: 10 Senior Admin: 8
Atlantic Southern State University	Public	HBCU	Master's Colleges & Universities: Medium Programs	.89 American Indian .84 Black .52 Latinx	Faculty: 15 Staff: 3 Senior Admin:7
Southeast State University	Public	HSI	Doctoral Universities: Highest Research Activity	.82 Latinx .53 Black .35 American Indian	Faculty: 13 Staff: 14 Senior Admin: 4
Northern Mountain University	Public	N/A **	Doctoral Universities: Higher Research Activity	.94 American Indian .75 Latinx .25 Black	Faculty: 3 Staff: 6 Senior Admin: 8

West Coast State University	Public	HSI	Master's Colleges & Universities: Larger Programs	.83 Latinx .37 American Indian .27 Black	Faculty: 3 Staff: 4 Senior Admin: 8
Western Private College	Private	N/A	Baccalaureate Colleges: Arts & Sciences Focus	.73 All STEM	Faculty: 6 Staff: 2 Senior Admin: 1
East Coast State University	Public	HSI	Doctoral Universities: Higher Research Activity	.81 All STEM	Faculty: 9 Staff: 7 Senior Admin: 9
Mid-Atlantic University	Private	HBCU	Doctoral Universities: Higher Research Activity	.76 Black .40 Latinx .35 American Indian	Faculty: 9 Staff: 4 Senior Admin: 2
Central Plains State University	Public	N/A**	Doctoral Universities: Higher Research Activity	.96 American Indian .44 Latinx .35 Black	Faculty: 10 Staff: 3 Senior Admin: 8
Southern Private University	Private	HSI	Master's Colleges & Universities: Larger Programs	.65 Latinx .35 American Indian .12 Black	Faculty: 9 Staff: 8 Senior Admin: 7
Midwest State University	Public	N/A	Doctoral Universities: Highest Research Activity	.75 All STEM	Faculty: 5 Staff: 7 Senior Admin: 9

**High population of Native American students

Data Coding and Analysis

The research team 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 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. 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). We met several times over the course of 10 months to discuss general categories or themes and how they related to one another. When we differed about particular findings for each research question, we reexamined transcripts, matrices, or themes in question and discussed it until consensus was reached (Fraenkel & Wallen, 2003).

Results

How Faculty and Administrators Defined and Identified STEM Talent

When it comes to characteristics that signal "talent", several STEM faculty, staff, and administrators continue to use academic skills (i.e. high test scores, strong GPAs, and classroom performance) as metrics for identifying student talent. However, many faculty members also identified student talent using broader definitions than traditional metrics. For example, several faculty members identified talent by also looking for a combination of indicators that signaled a student's potential for success in STEM: acuity, thirst for knowledge, ingenuity, eagerness/zeal, and grit (see Appendix A for specific definitions and frequency institutional agents mentioned each category). Consequently, faculty looked for a broad range of indicators to identify talent rather than just one. Looking for these additional qualities in students allowed faculty members to broaden the manner with which they identified student talent, consequently reducing the chances of missing talented students that may or may not have been identified through traditional achievement indicators.

Traditional Metrics. While faculty are using broader achievement indicators for talent identification, the majority indicated that they still use traditional metrics which include GPA, test scores and classroom performance. A biology faculty member at Southeast State University still advocates for these traditional metrics as well as *perseverance*:

> Well, you know, a lot of students come and ask to work with me and the first thing I do is I go and I look up their transcript and if their transcript is reasonably strong then I invite

> them to come to lab meetings and see if they still like us, you know. We discuss papers and so forth and, you know, take all the online safety classes you're required to take, you know, for working in a lab. And if they stick it out and do all that, then it shows they're really interested and then we start incorporating them into the lab. If they even fail the transcript test, what you tell them is, you know, working in a lab is going to be a lot of work and you need to get your academics in order before you take on new responsibilities.

A Learning Assistant for a STEM intervention program at Southeast State University mentioned that these indicators are the best predictors for future success for STEM-related leadership or roles such as becoming a tutor or learning assistant. Grades are still considered when selecting leaders for their STEM program:

> The main thing [I look for] is whether they took the class and received A's or B's, or a recommendation from the faculty. I myself and other [Learning Assistants] would recommend a student that we think will probably do well in the course.

Eagerness and Passion for STEM. Many faculty identified talent through students' demonstrating eagerness, passion, and enthusiasm for STEM. These faculty discussed the students' passion for science, and some also mentioned student desire to engage in scientific research. Several faculty mentioned the importance of passion alongside academic skills such as test scores and class performance in order to identify talent. A biology Professor at East Coast State University explains the importance of enthusiasm and what this looks like:

> Yeah. Enthusiasm is you [contact me]—you send me an email, you come to my office, you basically [are eager to learn]. Enthusiasm is, if I don't know you, you approach me and you're like, "Oh, wow. I'm interested in learning more about this field," or, "I'm

> interested in learning more about that [topic].” Enthusiasm is really—I guess also it’s taking the initiative, being proactive.

This dedication to STEM is what represents a student’s passion or eagerness to be involved in the field. Although eagerness and zeal is important to many faculty, others look for a student’s curiosity and desire to learn, described as a thirst for knowledge.

Thirst for Knowledge and Skill Development. Defined as inquisitiveness, curiosity, and engagement, having a thirst for knowledge differed from eagerness and zeal in that faculty specifically looked for a student’s curiosity rather than simply having a passion for STEM. They would recognize students that ask a lot of questions and are naturally curious, revealing deeper thinking. Several faculty mentioned that they looked for students in their classrooms who demonstrated the ability to think critically and/or who displayed a sense of inquisitiveness to signal that a student had potential and might be both seriously interested in pursuing STEM as well as worthy of investing faculty time to cultivate their interest. Faculty emphasized that curiosity is imperative in STEM fields and that a student who continuously asks questions displays a level of STEM talent because they are already thinking like a scientist. For example, one department chair and professor in engineering at Mid-Atlantic University explained:

> Are they naturally inquisitive? Do they care about digging deeper?”—those are usually the students who ask different kinds of questions. Or if I give ‘em a topic, they’ll come one day and say, “You’re talking about...water treatment–and I found this great paper. I went online..” that’s an inquisitive mind! That person is interested in learning something more.

Beyond displaying the ability to think and question, faculty also mentioned that they identified talented students as those who demonstrated strong scientific skills that contribute to success in several STEM disciplines. Several faculty mentioned the importance of skills such as mastery of laboratory techniques, possessing a particular attention to detail, and understanding how to apply theoretical knowledge in laboratory work. A professor in psychology and STEM program director at East Coast State University initially identified talent by looking out for highly motivated students--those who have a thirst for understanding the course or STEM discipline. The professor stated the importance of identifying various types of strengths and areas for growth in a student who might perform well academically, but may just need additional guidance in scientific skills development in order to do well:

> In some cases, very bright students who are highly motivated, I invite them to come and work in my lab...Their vocabulary is very important, for example, what terminology they use. What are the topics that they talk about, for example? The kinds of questions that they ask in class will also tell me a lot about their talents, but also because some of our courses have a laboratory component, right, one can see even more hands on [work as skill] than just brainiacs right. I remember a student who was an "A" student in the lecture for Foundations and he got a D in the lab, you know, so [the concepts] didn't translate, right. We had to sit him down and say, "You have to pay attention to things that you do with your hands because it's important as well."

Grit. Because many faculty talked about the importance of looking beyond high grades to identify talent, a few faculty explained how a student who demonstrated commitment and perseverance could offset a poor grade in a course. These faculty identified several qualities in students that fall under grit; these characteristics included perseverance, determination, ambition, and persistence. For example, a professor in biology at East Coast State University said, "I think that honestly, I basically look for one trait. My only trait that I care about is perseverance." Similarly, a faculty member and director of a STEM intervention program at West Coast

University explains that from her own experience, one way she has found to select students is to invest in students who demonstrate grit:

> Students all want to come in and do research. And you can't accommodate everybody so you have to be selective to some degree. And so… the faculty [will say], "Well I only I'm going to take an A+ student." But the ones who really understand will say, "I'm not going to do that. I'm going to take the B student who looks like they're motivated and they're going to stick with it." And that student winds up very often being the best... We're looking for -- because the A student is going to do really well anyway I mean no matter what. And that you can throw them in a whatever and they're going to rise to the top anyway just because that's who they are. But it's the other ones, that if you just water them a little bit [to cultivate talent] then they have that perseverance [to stay in STEM], they have that grit the "stick-to-it-ness."

While related to grit in terms of identifying students who display the ability to persist, some faculty seemed to explain aspects of grit specifically related to underserved students in STEM, such as underrepresented racial minorities and low-income students. A professor in biology at East Coast State University (one of the four HSIs in the study in an urban center) said in describing the obstacles students face:

> I just see how many obstacles a lot of our students have to overcome… It made me really appreciate my upbringing because I look back and I'm like, "Oh, my God, I didn't have to do any of that." You know, like college was so easy for me now thinking back like 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, or have a lot of family members say, "Why are you going to college? Why are you wasting your time, you know?" There are so many physical and also like emotional--psychological I

> guess, obstacles that our students face. And I'm – like usually, really, really impressed and inspired by them that they're still here, you know. They can overcome so much and still be so upbeat, so positive and try so hard and still do so well in school.

Several faculty similarly echoed the sentiment of inspiration and admiration of talent to persevere, especially for students who have faced and overcame several obstacles as they have pursued their STEM studies. Many faculty acknowledged that students from underrepresented racial/ethnic backgrounds have several other priorities and challenges to deal with on top of a demanding STEM course load, which led faculty to have more empathy and understanding for why a student might have a slightly lower grade but is juggling multiple responsibilities and is capable of pursuing a STEM major.

Ingenuity. Ingenuity refers to students' creativity and innovation. A few faculty members expressed that creativity was another indicator of student talent. For example, the quality and creativity of how students answer questions was as valuable as getting a certain number of questions correct. One associate professor of mathematics at Southern Private University shared a story of a student who demonstrated creative thinking in a math courses:

> Largely [I see talent as] being able to think creatively about math. We had one math major who, actually unfortunately, did not end up completing her degree, but she was in my college algebra class and I had a bonus question on a test. The answer she came up with, I thought, was more concise and better than the answer I had thought of. I wrote on her test something to the effect of, "Are you sure you're not a math major? Why don't you come talk to me?" She ended up changing her major to math—I forget what it was prior to that, and was doing well before personal issues got in the way of completing college at all.

Notably, after identifying the student as someone with potential, the faculty mentor took the extra step to reach out personally and talk to the student about being a math major. It is also important to note that although she ultimately did decide to become a math major, personal issues impacted her ability to complete the degree. We will return to this issue in a later section focusing on how institutional agents support and cultivate students they identify.

Acuity. Different from simply earning high grades on exams and assignments, acuity is a student's ability to understand and pick things up quickly. As a few faculty described, and representing a fixed mindset, a student's acuity demonstrates inherent skill in understanding material expeditiously. A couple faculty members identified students' ability to quickly understand and master content knowledge as a signal for talent. For example, a professor of Computer Science at Southern Private University states:

> It's pretty easy to identify actually. Yeah, and the good students learn things right away, easily, quickly. They can think abstractly, they can see a problem, decompose it, put it into pieces. They understand how the components work. They understand how computing and algorithms work in any language. They pick it up easily.

The faculty member described components related to innate perceptions of talent, such as the ease and speed which students comprehend the material.

While institutional agents shared several broader indicators of student talent, they also discussed some strategies they employed to determine the presence of these traits. Faculty mentioned taking extra effort to get to know the students in their classes so that they could get a better sense of which students displayed curiosity, or which students may have been missing class due to family-related or financial-related issues rather than simply a lack of interest or effort. The next section reveals several strategies for cultivating talent.

The Role of Mindset in Cultivating Talent for URM Students

Faculty and administrators at each campus mentioned the importance of both their own mindset as they identify talent, as well as cultivating talent by getting students to shift mindsets about STEM success. Institutional agents talked about seeing "potential" in all of their students to succeed and their belief in the college or university's responsibility to nurture that talent. Additionally, we found that some institutional agents spoke of being "culturally aware of who they are", as one faculty member at Northern Mountain University put it, to understand how "potential" looks very different for the population of students their institutions served. While many faculty and staff at the MSIs in the study spoke of being aware and responsive to the unique challenges URM students face in STEM disciplines, participants at the PWIs also spoke about the importance of addressing equity in STEM by actively supporting underrepresented students. For example, one college president spoke to West Coast University's role in identifying and cultivating talent:

> See, we struggle in this society on how to identify talent, because we have this perception that talent looks like X. When we think about areas of many of the STEM areas, we—it has been a male-dominated field. When you have these young girls in elementary school, and they have interest and aptitude in math, or science, or whatever, how is that fostered? Is it encouraged? That's an area that I have some strong [opinions]—it's not just STEM. It's just generally. I think it's important that we tap into people's potential and help encourage them to let that grow.

As an HSI, it is notable that senior administrators hold a mindset that sees and actively works to nurture the potential in their diverse student population. HBCUs have long held this culture of seeing and activating potential. In explaining his philosophy about working with students, a STEM department chair at Mid-Atlantic University said he mentors them "one at a time, by working closely with the student and really recognizing their individual potential and bringing it out". He shared a story of working with a Black woman who struggled in her physics major for most of her time in college until she came to him to ask for some help during her senior year. After working with her and connecting her to colleagues and experiences, and providing guidance on graduate school, the student went on to pursue a PhD in a STEM field:

> If I had taken that line (i.e. distinguish between students with potential - and worthy of further investment - and those who lack potential) to say that this student is not an A-student, but rather a B-student type of deal, maybe on the lower B scale, I would have just completely ignored her, and she would have just probably finished her degree, and that would've been it. Now she's an African American about to pursue a PhD in material science, or materials engineering.

While it is important for a faculty member to believe that their students have potential in order for that faculty member to actively support a student's success, we also saw evidence of faculty and staff cultivating students' mindsets about their own potential. A program coordinator for a STEM transfer program at the Southeast State University talked about the importance of Dweck's Growth Mindset in cultivating students' talent:

> So, the students are really a great motivated group of students. I don't know if anyone has talked to you about how much this office thinks about Carol Dweck's work on growth mindset? It's quite prevalent and so that is one of the things that we often encourage of students to actively think about and have a lot of metacognitive processes around that… our Student Success conferences year's theme is growth mindset. So, there is a lot of effort and thought around having students think about changing the way they perceive whether or not they can learn. And in some of the students I have worked with I have encountered sort of what Carol Dweck called the fixed mindset of, "oh I can't do

> this". This is not something that's in my wheelhouse [of expertise]. It's just not for me. And I found it very challenging to help students reframe that.

Thus, while many of the faculty and staff spoke generally about characteristics that aligned with a growth mindset, some faculty and staff either received training or took it upon themselves to familiarize themselves with Dweck's work, and shared how they utilized the theory in their classroom or programming to support students and increase retention in STEM. The next section will expand upon ways that talent is cultivated by faculty and staff, many of whom employ the notion of shifting mindsets from fixed to malleable.

Cultivating Talent: How Institutional Agents Position Undergraduate Students for STEM Success

In examining how faculty, staff, and senior administrators nurture undergraduate STEM talent, we often found that these institutional agents utilized a combination of strategies to support students' persistence in a STEM major and beyond toward a STEM career. We found that the attitudes faculty and staff held about their students (e.g. views of students' potential to succeed, level of appreciation for the barriers and challenges that students face.) contributed to the degree to which faculty and staff engaged in talent cultivation strategies. Stories from participants provided evidence of cultivating talent from three of the original five asset bundles that Johnson & Bozeman (2012) suggested in their Asset Bundle Model to support and advance URM students in STEM: science socialization, network expansion, and material resources. We discuss common themes and unique ways in which faculty cultivated talent with respect to these three asset bundles.

Science Socialization. A key component of nurturing students' STEM talent involves providing opportunities for students to see themselves as scientists and become better aware of their own potential. Science socialization played out differently across campuses but often involved both affective encouragement and tangible resources that allowed students to adopt the "norms, values, behaviors and social skills" relevant to science careers (Johnson & Bozeman, 2012, p. 6). For example, at West Coast State University a faculty member and director of a STEM intervention program described the validating culture fostered for undergraduate students on his research team:

> They don't work for me. We collaborate….They're not workers. They're not slaves. They're not bottle washers. They're researchers….we consider each other to be colleagues. We've treated the undergraduates in the same way. They're our colleagues. They aren't an employee. They aren't someone that's there to get work done for us. They are our colleagues. We try and treat everybody like everybody could have an idea for a paper. Everyone could contribute to a research presentation. Everyone that wants to do something is welcome to do it. I think that that empowers. Well, I think for a lot of students that's empowering.

Students in this research team are not only equipped with practical knowledge and training to conduct research, but they are also empowered by recognition from a faculty member as a colleague (Carlone & Johnson, 2007). By treating students like scientists who are capable of producing research ideas, this faculty member models scientific socialization through which students begin to envision themselves as scientists and STEM professionals.

Another opportunity that faculty provide students in an effort to cultivate their science talent is by working with students to produce original research and attend national research conferences. A faculty Biological Sciences at Atlantic Southern State University describes the impact of this practice:

> That’s a requirement in my lab--Scholarship Day, and everyone has to apply to do some sort of national conference….With the conferences, they all apply for travel awards. And we’re about a 90% [participation] rate, where everybody’s gotten travel awards and can go places. So, it’s just a matter of opening these opportunities up for them. Once they get to that national meeting, they're like hooked because they see all these people who look like them, and it just really makes a difference.

Providing access to national conferences gives students exposure to the field. However, in addition to exposure to the field, the faculty member notes the importance of connecting students with academicians and practitioners that look like them at STEM conferences that have diverse students and faculty participants. This aspect of science socialization allows students to envision themselves as scientists and feel included and welcomed into the scientific community, which is especially pivotal for students from underrepresented and marginalized backgrounds (Johnson & Bozeman, 2012).

Additionally, some faculty and program directors shared that key experiences, such as attending conferences, can not only help a student develop leadership skills, confidence, and science experience, but can also have a psychologically transformative effect on a student that bolsters their commitment to pursuing a STEM career or STEM graduate study. A professor in engineering at Central Plains State University described how an opportunity to travel internationally for a STEM conference completely changed a student’s trajectory:

> Sometimes [having a student attend a conference] pays massive dividends. One particular example is, I think, in 2006, I took a group of students, along with some other faculty members, to Korea, and we had one student who—I don’t think had traveled a whole lot. The person that came back from that trip was in the same body as the person that left, *but they were not the same person.* Their view of the world had totally changed.

Indeed, conference visits provide students with knowledge that they may not otherwise experience in lab or lecture and therefore provides unique insight into the prevailing research and new research in STEM disciplines. Moreover, providing experiences that a student normally would not have had access to can be transformative since it can open a student's mind to new possibilities for learning experiences and career pathways, much like what ensued with the engineering student described at Central Plains. Faculty we interviewed at several of the institutions worked with undergraduate students in their labs. One life sciences faculty member at Southern Private University shared how offering a student an opportunity to work in her lab in his last year was a significant and transformative milestone for him:

> [A student] was heading into his last year and he wanted to do research, and no one had ever invited him. I said, "You can work in my lab this summer if you want. At this point in the year, I have no way of paying you." He was the most eager, enthusiastic, and productive student I had in lab all summer...it was just so powerful--he said, "You know, there's always been a few students around who've done research. It seemed like a wall to me, and on the other side was the research environment. I didn't know what it was. Now I'm over the wall, and I'm loving it." To feel that he was locked out of [an experience that he grew to love], that bothered me. That really bothered me.

Some faculty members were intentional in providing authentic research experiences as early as possible. One faculty member in the Biology department at Midwest State University made it typical to have undergraduates publish in his lab:

> What we encourage them to do is find a research project where they can contribute. Meet the different graduate students. I look back, I probably, I don't know 15 or 20 papers that have undergraduates on them… We have a few out of our lab where the undergraduates are the first authors...By two semesters, if they're doing well they should get involved in

> some publication in a supporting role. If they stay for a second year, we're encouraging them to define a project that they start taking ownership of. Usually, they'll do it with somebody, but they may very well take the leading role.

One faculty member in the department of Biological Sciences at East Coast State University incorporated step-ahead mentoring in his lab in order to expose students to the challenges with balancing productivity and training peers:

> I try to assign the undergraduate students a high school student in the summer. The idea, again, is I want—from the mentoring perspective, I want people to really, fully engage the people that they're mentoring. I engage. I do mentor the other people too. I also want my people to mentor [other students], because part of this is a learning experience for them to run a lab. To me, it's important for them to understand how to balance what you need to get done with helping other people.

While we discuss more themes related to mentoring in the following section, this example highlights how the faculty member aimed to socialize students to learn how to train others while doing research so that they developed important scientific leadership skills.

Network Expansion. Considering social capital as a resource embedded in social networks, students expand their networks by "building positive social capital through mentoring relationships, involvement in extracurricular activities, and peer influence" (Johnson & Bozeman, 2012, p. 8). As the provost at Atlantic Southern State said, "Part of why the undergraduate research paradigm works so well is there is a direct mentoring experience. So when it's done well, not only is someone mentoring you in research but they really become your best connection for lots of things [like resources and information]." Connections to faculty and staff support talent development when these institutional agents share their knowledge and guidance in order to open doors for students to obtain resources, navigate pathways, and expand their networks to other colleagues in the specific STEM discipline.

While it is important for underrepresented students to be exposed to scholars and practitioners from similar backgrounds as their own (Johnson & 2012), it is also important for them to have mentors that belong to the dominant group in order to gain access to expansive and well-connected networks. For instance, an associate professor in the life sciences at Southern Private University shared how she was able to connect one of the students of color at her institution in order to help the student get access to a scholarship:

> I was like, "Oh, I know about this scholarship over at A&M." I found out about it when I was on sabbatical. I said, "I know about this scholarship [for graduate study]. Let me introduce you to this guy." I emailed him and I said, "Hey, have you filled out these—you know—[scholarships]?" "No, I haven't" [he said]. I said, "Okay, I'm sending her over. I'll connect you." Over spring break, she met him, and she was admitted. She got the scholarship like right away. Yeah, and so she said, "He helped me fill out the application." She was like, "I filled it out while I was there."

Another way students have gained access to important networks is by applying to grant-funded STEM programs, which often allow students to engage with staff and faculty outside of the classroom. For example, a program coordinator at East Coast State University supports students in LSAMP, an NSF-funded STEM program, by engaging students and asking questions about their goals in order to determine how to connect students to the right opportunities for them:

> I definitely see their confidence level definitely goes up because a lot of students that I see that come to LSAMP... when every student applies to the program and gets accepted, I will sit down with them and I will say, "Okay, tell me about yourself. What do you want to do?" If you don't know, that's totally fine...And then I tell them, I ask them, "What do

> you see yourself getting out of LSAMP?" Then from there I dig deep and I try and figure out what they wanna do with their life, their dislikes, research, internships. Some students, they say, "I wanna start doing research. I wanna get an internship because I want to go to grad school." It's those students that I really try to help and try to get the internship opportunities and whatever they need.

Since these programs include built-in staff support, structured mentoring and cohort models, students gain increase their social capital by establishing their own networks of peers and mentors.

Material Resources. Connected to financial capital, Johnson & Bozeman (2012) contend that targeted financial interventions, such as scholarships and grants, support the retention of underrepresented students in STEM. Indeed, we found that institutional agents went above and beyond to not only recognize, but actively address students' financial needs in order to remove barriers for those with potential to succeed in STEM. It is likely that recognizing the needs of these students helps them to feel successful and motivates further performance, consequently positioning them for future success. Faculty and administrators also found ways to meet students' financial needs while investing in their talent development. For example, the dean of the College of Agriculture at West Coast State University discussed the importance of helping students find scholarships to offset their unpaid internships, which they pursued in order to gain valuable experience in the field:

> And we also help a lot with scholarships...we do have a lot of scholarship money and we use that to help students offset their unpaid internship programs because we know that if they have that internship that they can be more successful; but again it's – often times our students don't have a lot of external resources, so we need to find ways to help them [financially] be successful [in STEM].

Additionally, the director of academic success at West Coast State University described paid opportunities that not only supported students' financial stability but also gave them valuable experiences that allowed them to stand out as competitive candidates:

> We hire all these students so that by the time that they graduate, that on their curriculum vitae [for] grad school shows that they've tutored, [provided] supplemental instruction [for other students]. That they have TA'd, if you will, and that they've done research with faculty. That's now a candidate that pops up [distinct from candidates from other places]. I remember talking to a faculty member from [another institution] who says, "I had to call you because I really couldn't believe that this student had done all these things." I said, "No, actually the student did all those things and, actually I'm going to tell you that it was super hard for her to do all those things. She had the opportunity [to interview]. When you talk to her, she was able to answer all [questions] and be somebody that you would want to work with to do research.

Because institutional funding for student research varied on campuses, faculty who had grant funding used part of their budget to pay their undergraduate students working in their labs. At Western Private University, the institution was well resourced and allocated a significant amount of funding for students who wanted to do research with faculty and even paid for travel to academic conferences. Mid-Atlantic University, an HBCU, was less resourced, but even small stipends helped increase access for students who often are constrained by the need to work while in school:

> I think stipends are important just to reward the effort... Some of them that you want to keep—the guy that I told you that was shy, I didn't know but he was working in a convenience store at night. I didn't know that, but I was paying him tiny stipends. When I

> knew that I said, “Son, why didn’t you tell me?” The time he was spending in the store he could doing something else. Stipends are fine just to value the work they place.

In sum, faculty and staff cultivated talent by finding financial resources to support students. Especially for students coming from low-income families, funding to allow them to participate in these science experiences was key to maintaining their interest and to their professional development as scientists.

Discussion and Implications

Overall, while many still use traditional metrics such as grades on exams and assignments to identify undergraduate STEM talent, several faculty and staff also used a broader definition of talent that included eagerness/zeal for science, thirst for knowledge and skill development in general, grit, and acuity. Though traditional metrics and acuity are often associated with innate talent, many of these other characteristics signals talent falls in line with a growth mindset rather than a fixed mindset, wherein students begin to believe learning STEM content is not in their nature (Dweck, 2008). Notably, several institutional agents in the study were familiar with psychology literature that they applied to their daily work. In particular, some faculty were well-versed in Dweck’s Growth Mindset and Duckworth’s conceptualization of Grit, and used these concepts to guide their actions as they considered how to best identify and cultivate STEM talent at their institutions.

A major finding is that these broader definitions of talent are not necessarily discernible without profound inquiry and engagement with the individual student. Instead, talent is expressed in various ways and is fluid rather than static (Plucker & Barab, 2005; Cliff & Hanslo, 2009). As a result, faculty who make efforts to get to know their students are more capable of properly identifying talent. Students who make the effort to contact faculty are also rewarded with recognition for interest and passion in STEM. However, once talent is identified, it is not enough to simply leave students alone to find their way through their undergraduate careers. Institutional agents actively cultivated talented students through science socialization, network expansion, and material resources, three of the asset bundles Johnson & Bozeman (2012) propose to help advance underrepresented students through the scientific pipeline. Faculty provided science socialization to students by treating them like colleagues, recognizing they were capable of producing important research, making it typical for students to publish in their research teams, and creating opportunities so students could attend national conferences where their commitment to pursue a STEM career was strengthened and they could see themselves represented in the profession. Faculty also cultivated students' talent by giving them opportunities to expand their networks and gain valuable social capital via mentoring relationships, involvement in grant-funded STEM programs, involvement in colleague networks, and participation in scientific training experiences. Lastly, it was important for faculty to not only recognize but also address students' financial needs by providing material resources. Faculty helped remove financial barriers for students by helping them find scholarships, grants and funding to pursue experiences that allowed them to become competitive applicants in STEM careers and graduate school.

The success or failure of institutions in facilitating 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; Hurtado, Eagan, Cabrera, Lin, Park, & Lopez, 2008; Perna, Lundy-Wagner, Drezner, Gasman, Yoon, Bose, & Gary, 2009; Seymour & Hewitt, 1997; Stage, Lundy-Wagner, & John, 2013). This success is attributed to their ability to focus on talent development, provide a safe and affirming educational environment in which students are put first, hold high expectations, and give the support and encouragement students need to succeed (Hrabowski, 2013).

Learning how exemplary campuses and institutional agents identify and cultivate talent via their STEM programs and classroom practices helps other campuses that face inertia in STEM degree production. Specifically, educators' use of broad definitions of talent, applying multiple indicators when identifying talent, and the application of various strategic activity when cultivating talent guarantees that a larger pool of students will be considered proficient in speaking and thinking within the norms of scientific inquiry. 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 within an institution, but did see "lead" departments innovating to increase and diversify STEM majors. There was evidence 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 broad thinking about how to identify talent in their daily work showed how views about talent are embedded in the organizational context (Murphy & Dweck, 2009) not only has implications for their own behavior but can also be reinforced in their environments.

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 whereby faculty, program directors, and even senior administrators can play a role in encouraging students toward success in STEM. For example, large introductory STEM classes are a critical opportunity for STEM departments to strategize how to identify talented students beyond those who perform well on assignments and exams. With the rise of active learning pedagogy in these courses, the opportunities to get to know students on a deeper level can further help faculty in identifying students to nurture and invest in. Moreover, such practices of engagement have the potential to reduce equity gaps in science classrooms (Tanner, 2013) Further, this study demonstrates that faculty recognition goes a long way in developing student talent (Carlone & Johnson, 2007). 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). By getting to know students' passions and capacity to persevere, faculty can build relationships to advance student talent in STEM.

Cultivating talent does not stop with faculty. Upper level administrators support program directors and faculty are crucial actors in talent development activities. Indeed, the institutional agents we interviewed and institutions we visited, demonstrated 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 funding these successful programs. Department chairs can discourage behaviors that are antithetical to STEM talent development and reward behaviors that significantly advance degree completion in STEM. Faculty can train their graduate students and postdoctoral fellows with a mindset geared towards cultivating talent; this ensures that when these rising scholars become scientists 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 diverse STEM scholars and professionals.

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Appendix A

Chart of Definitions of STEM Talent

Talent Characteristic	**Definition**	**Number of Times Definition Was Mentioned**
Traditional metrics	Faculty identify students talent through traditional measures which they have defined as GPA,test scores, and classroom performance.	Faculty:19 Senior Administrators:3
Eagerness and Zeal for STEM Subjects	Under this definition, faculty identify talented students as having passion, desire, and enthusiasm for science.	Faculty: 22
Thirst for Knowledge & Skill Development	Many faculty have discussed students' desire for knowledge and to develop their skills through their inquisitiveness, curiosity, and engagement with science.	Faculty: 11
Grit	Grit describes student perseverance, ambition, persistence, and determination.	Faculty: 8
Ingenuity	Some faculty have identified talented students as creative and innovative.	Faculty: 3
Acuity	Acuity stands as a fixed type of measurement, where faculty have described student talent as having an inherent ability in understanding/picking things up quickly, and an ability to distinguish concepts expeditiously.	Faculty: 2