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Reflecting on the past year and a half, serving as President, I am pleased with the position of the Consortium and how the work of the board has grown the Consortium exponentially.

As I look forward into the next year, we have begun to codify new initiatives that will lead to more opportunities, and I am hopeful that the big steps that the organization has taken will lead to the consortium being the national “go-to” organization as a STEM resource.

There are many ways in which we are moving forward with regards to structure, policy, partnerships and opportunities.

Structure:
We are very proud to have a full staff that assists us with our ambitious efforts which has resulted in increased membership.

- Erin DeLuca, Director of Business Affairs
- Jennifer McNally, Director of Marketing & Communication
- Annette Suriani, Director of Meetings and Events
- Mary Bates, Director of Finance

Policy:
We have been active with informing policy on a national level by meeting in the White House with advisors to the President and on Capitol Hill with Senators and Members of Congress.

Business Development:
We have created new partnerships and sponsorships with companies such as STEM Ed Coalition, Pearson, Siemens Foundation, Apps For Good, Lockheed Martin, Jack Kent Cooke Foundation, and the National Association for College Admissions Counselors (NACAC) that will advance the mission of our organization.

Opportunities:
We are shaping opportunities for Consortium students and teachers through the Congressional Awards, Dow Chemical Company, NEPRI and Apps for Good.

A challenge to the Consortium and member schools:
What can member schools do to communicate opportunities to create a community of sharing and resources to share among the membership and the STEM schools across the nation?

How do we create a platform to strengthen our school to workforce pipeline for our student population?

Thank you for your commitment to NCSSS. I look forward to your continued support in all of the Consortium’s future endeavors.

Educationally Yours,
Crystal Bonds, President

Crystal Bonds is NCSSS President and Principal of High School for Math, Science and Engineering at City College in New York, NY.
Many of you may not know that since my last column in this space more than a year ago, in addition to my role as Executive Director of the National Consortium of Secondary STEM Schools (NC-SSS), I have been fortunate to become the Executive Director of Magnet Schools of America (MSA). As the name implies, MSA represents magnet schools throughout the country, about 2,000 of them.

Leading both organizations gives me an interesting vantage point on two education strongholds. I am afforded an opportunity to see the wonderful education provided to students in both sets of schools, as well as the challenges both are encountering.

Magnet schools grew out of the Civil Rights Act. An alternative to desegregating via busing, magnet schools were built to foster diversity and excellent education that students could choose to attend. Schools were developed around themes as well, which further enhanced the concept of choice. “Choice” has become a key element for magnets, giving students an option of schools beyond the one that is in their community.

Some STEM schools have been around for a lot longer. An initial focus on science, math and engineering, these schools added a rigorous and disciplined approach that included lab work and research above and beyond traditional high schools. While there are not as many STEM schools as there are magnets, they nonetheless have grown into their own, and with significant popularity.

Both types of schools bring tremendous value to their students. And what I find interesting from my unique vantage point of running both organizations, both are encountering interesting challenges as well. These challenges are ones which initiate with public perception, but which wind up influencing policy decisions in the nation’s capital.

STEM schools, as you know, have student testing as an entry point to admission. This process assures the school of having a student population that can handle and succeed in the rigors of the courses being offered. This selectivity also assures those on the outside, be they colleges or grant givers, that this student population is comprised of high achievers.

But increasingly to many on the outside, this selectivity also carries with it another description: elitism. There are some who say that some high achievers may not have a chance to test well for entry because they have not had the same access to a good education earlier on, or they have not had the financial wherewithal to gain that access. Moreover, the elitist tag suggests that minorities are the ones whose chances for that access are the most remote, creating classrooms that are far from heterogeneity, be it racial, ethnic, or socio-economic.

When you consider magnet schools you might tend to think, correctly so, that magnets do not have to worry about these issues. As schools that started out by resolving busing for desegregation purposes, these schools have always had diverse racial populations as a basic tenet. And given the growth in their popularity, they have had to resort to a lottery system just to manage their open admissions process. Add on top of that the assurance of access to these schools for students who live beyond
walking-distance, such as providing bus transportation, these schools have done a good job of avoiding many of the elitism challenges faced by STEM schools.

But this does not mean that magnets are without challenges. Here is their biggest one: magnets have moved beyond being just an environment for racial diversity. They have employed high academic standards in the schools themselves, and have applied their themed approach to their schools to make the education proffered one that can appeal to students on many levels, and one which further enhances “choice.”

Here then is the real challenge for magnets: In spite of the growth in the educational approaches and standards being offered by magnets, the public still views them as schools of the Seventies, as single-dimensioned approaches aimed at addressing desegregation. This challenge is borne out in the growth of charter schools and in the lack of growth of funding in Congressional budgets.

Magnets would like more awareness of the rigors of their educational environment and of the value of their heterogeneity. STEM schools would like more awareness of the value of the education and its importance to our inventiveness and our economy, as these students move through the educational system.

From my vantage point, straddling both types of schools, the challenges do not diminish the value, nor do they accurately describe the approaches. We ought to be working to enhance and celebrate their offerings. They both bring tremendous opportunity to our students, our children.

— Todd Mann
The theory of human capital (e.g., Becker, 1993) posits that societies benefit from thoughtful investment in education, health care, and other services that enable citizens to become more economically productive. Given finite resources, policymakers must decide which investments will yield the greatest returns in developing human capital. The Obama administration’s focus on science, technology, engineering and mathematics (STEM) education and careers over other fields reflects its belief that U.S. productivity in these fields is most vital to the nation’s viability (H. Res. 5116, 2010). The G. W. Bush administration signed similar legislation, indicating that the promotion of better STEM education has garnered bipartisan support (H. Res. 2272, 2007). Authors of recent national reports (e.g., Committee on Highly Successful Schools or Programs in K-12 STEM Education, 2011; Committee on Prospering in the Global Economy of 21st Century, 2007; National Academy of Sciences, 2010) concur that our nation’s continued financial, environmental, and military security rest on developing highly skilled U.S. citizens in STEM professions.

Theories of individual talent development situate economic theories of human capital in the context of the education system (both public and private), suggesting how talent can be optimally nurtured. Bloom (1985) posited that talented high school students may have a passion for a specific discipline and are ready to develop a self-identification as part of that professional community. Some may even be ready to benefit from systematic mentoring from practicing professionals. Considerable evidence (see Dai, 2010 for a summary) suggests that the manifestations of human abilities become increasingly domain-specific with progressive talent development. Therefore, general talent development models (Brody & Stanley, 2005; Gagné, 2005; Renzulli & Reis, 1997; Subotnik & Jarvin, 2005) can be justifiably applied to specific disciplines, including those in the STEM fields (Subotnik, Duschl, & Selmon, 1993; Subotnik, Pillmeier, & Jarvin, 2009).

A limited number of highly selective high schools specializing in STEM education have existed for many decades, encouraging youth with identified STEM talent to pursue careers as STEM leaders and innovators. As members of the National Consortium for Specialized Secondary Schools of Mathematics, Science, and Technology (NCSSSMST), many of these selective schools benefit from scholarly interaction and dialogue on how to best serve their students. However, research on selective STEM schools has largely been limited to internal program evaluation, making it difficult to assess any causal inferences related to effective school features and practices. As of the writing of the present study, one in-progress study sought to evaluate the effectiveness of these schools using a quasi-experimental design (National Research Council, 2011), but published results of that study were not available.

Even if evidence should accumulate showing the effectiveness of selective STEM schools, the nation’s many challenges will require more than an elite cadre of STEM leaders. The nation will also need “a greater portion of populace that is better prepared in STEM, and generally more STEM literate” (Lynch, Behrend, Burton, & Means, 2013, p. 2). Expanded views of gifts and talents (Gagné, 2005; Renzulli & Reis, 1997) and policymakers’ priority of developing a greater proportion of young
people with rigorous STEM training provide justification for broadening STEM-specific talent development frameworks to include all students with the interest and motivation to pursue them. Students’ latent talents may emerge when they have opportunities to interact with engaging and enjoyable STEM curricula—a process that has been described as emerging “opportunity structures” (Lynch et al., 2013, p. 4). Even students who do not go on to pursue advanced degrees or STEM careers need a better understanding of these disciplines to become informed, productive citizens (National Research Council, 2011). To this end, the President’s Council of Advisors on Science and Technology (PCAST, 2010) recommended creating 1,000 new STEM schools (800 elementary and 200 high schools) over the next decade.

New STEM schools are proposed across three broad categories: (a) selective STEM-focused schools, (b) inclusive STEM-focused schools, and (c) STEM-focused career and technical schools (National Research Council, 2011; PCAST, 2012). Because new STEM-focused high schools are developed based on local communities’ needs and resources, they are likely to adopt an extremely wide range of policies, programs, and practices. In reference to inclusive STEM-focused high schools, Lynch et al. (2013) noted, “[T]hey may share common goals but there is no explicit theory of action that undergirds how they function; they are too new on the scene and varied in their designs and origins” (p. 5). Even greater variety in school design and implementation is likely to exist when all three categories of new STEM-focused schools are considered holistically.

The proposed proliferation of new STEM schools creates a vital and unmet need to understand the myriad of factors influencing the success of all specialized STEM high schools in fulfilling their own missions (Subotnik, Tai, Rickoff, & Almarode, 2010), as well as contributing to the broader societal goal of enlarging the pool of STEM talent within the United States. Recent efforts made to further describing and studying factors influencing STEM schools include the implementation of case-control studies of effectiveness in inclusive STEM high schools (Lynch et al., 2013; Means, House, Young, Wang, & Lynch, 2013); however, this line of research is still nascent and limited in scope. Additional exploratory studies that identify potential “critical components” (Lynch et al., 2013, p. 5) of effectiveness across different types of STEM-focused schools will greatly aid enhanced understanding of “what works” in a broader range of settings. The National Research Council (2013) articulated this research need: [M]aking informed decisions about improvements to education in STEM requires research and data about the content and quality of the curriculum, teachers’ content knowledge, and the use of instructional practices that have been shown to improve outcomes. However, large-scale data are not available in a readily accessible form, mostly because state and federal data systems provide information about schools (personnel, organization, and enrollment) rather than schooling (key elements of the learning process). (p. 4)

The first step in creating a research agenda is to identify the population of schools that can legitimately be designated as STEM schools and describe current practices in those schools. To that end, we addressed the following questions across a national sample of STEM-focused high schools:

1. What are teachers’ and administrators’ perceptions of the importance and frequency of various curricular and instructional practices in STEM-focused high schools?

2. What are the different structural features (e.g., admissions policies, population served, school type) of STEM-focused high schools?

3. How do administrators perceive the roles of teachers in curriculum development, the critical qualities of teachers in a STEM school, and the ways outcomes should be evaluated?

**METHOD**

We conducted an extensive search to identify the sampling frame of STEM high schools throughout the United States. We identified a total of 949 unique STEM school by searching websites, reviewing articles identified through electronic searches using key search terms, contacting state departments of education, and soliciting names of schools from the National Consortium of Specialized Secondary Schools of Mathematics, Science, and Technology. These schools served as the sample for the study.

To develop the STEM administrator and STEM teacher survey for the study, we first observed and interviewed key stakeholders (teachers, students, and administrators) in 12 STEM high schools. Using the qualitative data from these visits, we inductively coded a comprehensive set of curricular and instructional strategies and practices, school policies, and school culture factors that were present at...
the STEM schools. Common features across schools, especially those that seemed to represent best practices in STEM education based on the literature, were developed into item stems for the surveys.

The 48-item administrators’ survey was divided into five sections: Professional Culture, Curricular and Instructional Practices, Policies and Procedures, Description of Practices, and Demographics. In the Professional Culture and Curricular and Instructional Practices sections, one response scale focused on administrators’ perceived importance of each item; the other scale assessed the frequency with which administrators perceived that the practice occurred. Only the importance of each item was measured in Policies and Procedures. The Description of Practices section contained four open-ended questions regarding faculty policies and program evaluation. Finally, the Demographics section included questions about structural features of the school as well as admissions criteria, course offerings, and students’ eligibility for free and reduced lunch.

Importance was measured on a 6-point Likert-type scale with anchors ranging from unimportant (1) to essential (6). The Frequency scale response options were (1) never, (2) once or twice a year, (3) once or twice a grading period, (4) once or twice a month, (5) at least once a week, (6), and every day (6). Both scales included a not applicable option.

The 41-item STEM teacher survey was comprised of four sections: School Climate, Curricular Approaches, Instructional Strategies, and Learning Environment. The first three sections of the teacher survey used both the Importance and Frequency scales, but only the Importance scale was used in the final section.

Sample

We sampled all 949 identified schools by sending hard copy and electronic versions (via e-mail links) of the survey to each site. Administrators were asked to forward copies of the teachers’ surveys to five of their faculty members. Two hundred and five administrators and 777 teachers completed the surveys. Teachers from 291 unique schools completed the surveys, indicating that teachers at some schools chose to respond even though their administrators did not. Respondents were not asked for personally identifying information, but were asked to supply the state in which their school operates. The geographic distributions for the administrators and teachers who responded to the survey are shown in Figures 1 and 2.
SCHOOL AND STUDENT CHARACTERISTICS

School Structure and Demographics

Of the 205 administrator respondents, the largest number reported that they served a student population from urban areas (38.0%), followed by suburban (31.2%) and then rural areas (19.0%). Some administrators (7.8%) reported serving students from multiple urbanicities.

The administrator respondents identified a wide variety of school types. As indicated in Figure 3, the greatest percentage (25.9%) classified their school as a comprehensive high school; sizeable numbers categorized their school as a magnet school (19.5%) or as a charter school (16.6%). Nearly 10% of the administrators selected multiple school types to describe their schools. The vast majority (86.8%) of respondents described their school program’s organization as full day.

School Size

Approximately half of the administrators (50.2%) reported schools serving more than 400 students; approximately one-third (34.1%) reported between 200 and 400 students; and 12.7% reported serving fewer than 200 students.

Approximately half of the schools in the sample (48.2%) employed fewer than 30 teachers and the other half (51.2%) had more than 30 teachers. Slightly more than half (60.3%) had three or fewer administrators, while in a sizeable minority (39.7%) more than three administrators were on staff.

Admission Criteria

Administrators were allowed to select more than one response when indicating criteria used for admission to their schools. The most frequently reported criterion used to select students (45.4%) was students’ grades, report cards, or transcripts. More than a third of respondents (40.0%) reported using no admission criteria for student enrollment, indicating these schools were inclusive STEM-focused high schools. Figure 3 summarizes the responses to this item. Other admission criteria added by respondents included lottery systems, auditions, and residency requirements.

Student Characteristics

About 28% of administrators in the sample reported serving a student population with less than 25% eligibility for free and reduced lunch; approximately the same proportion (27%) of respondents were from schools with 26% to 50% student eligibility. Slightly fewer administrators reported serving populations with 51% to 75% eligibility, and even fewer served populations among the highest category of eligibility (76% to 100%). Despite these differences, a full range of school-level SES levels was represented in the schools responding to the survey (see Figure 4).

Student gender ratios were well balanced at nearly all of the schools surveyed. A small percentage (4.5%) of schools served fewer than 25% or greater than 75% female students. The survey did not ask administrators if their school was a single-sex school, which may have been the case for these few schools.

ANALYSES OF ADMINISTRATORS’ AND TEACHERS’ SURVEY RESULTS

We used descriptive statistics to summarize administrators’ and teachers’ responses to the survey items. Medians were selected because of the ordinal nature of the data and the highly skewed response patterns for many items on the Importance scale (Hinkle, Wiersma, & Jurs, 2003). We reported these statistics for respondents’ choices on both scales of the survey items. We also examined items for which there might be discrepancies between respondents’ perceived importance and reported frequency of use by
calculating the difference in medians. We considered more than one point of difference between the medians on the two scales to be indicative of a potential mismatch between perceived and enacted priorities. For some items, this discrepancy was not problematic due to high importance practices that would not be expected to occur frequently. But for many other items, we believed it was important to compare the differences between responses on the two scales. As another way to describe the relative importance of the items on the survey, we reported the percentage of respondents who selected one of the two highest possible importance scale rating categories (very important or essential) for each item.

Administrators’ Survey Results

Professional culture. Two items, Encourage teachers to ask open-ended questions with no single answer of solution path and Provide students with opportunities to participate in extra-curricular activities, received a median importance rating of essential by the administrators who responded (see Table 1). No Professional Culture items received a median frequency rating of every day; however, the following items had a median rating of occurring at least once a week: Allow teachers flexibility in modifying curriculum; Encourage teachers to ask open-ended questions with no single answer of solution path; Provide students with opportunities to participate in extra-curricular activities; and Provide specialized counseling services for students’ social-emotional needs. The only item on the Professional Culture section with a greater than one point difference in medians between the two response scales was Recruit students from culturally diverse or underrepresented groups (e.g., females, African Americans, Native Americans, SES). Although administrators viewed this practice as very important, it only occurred on average once or twice a grading period, which may reflect their recruitment and admissions cycles.

Although STEM administrators generally rated most items in the Professional Culture section highly, differences existed among items in the percentage of administrators who selected either very important or essential. Over 80% of administrators rated within-field teacher collaboration and sustained professional development as very important or essential. In contrast, less than 50% of administrators rated Collaboration between STEM and non-STEM teachers as very important or essential. Figure 4 shows the percentage of administrators rating each Professional Culture item as very important or essential.

<table>
<thead>
<tr>
<th>Item</th>
<th>Median Importance</th>
<th>Median Frequency</th>
<th>Median Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Communicate a STEM-specific vision of the school</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>2. Provide scheduled time for teacher collaboration within each STEM discipline</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>3. Provide scheduled times for teacher collaboration across STEM disciplines</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>4. Provide scheduled times for teacher collaboration between STEM and non-STEM disciplines</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>5. Promote change through faculty involvement in decision-making</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>6. Provide sustained opportunities for teacher learning within the school</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>7. Allow teacher flexibility in modifying curriculum</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>8. Conduct observations of teachers focused on their use of inquiry-based pedagogy</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>9. Encourage teachers to ask open-ended questions with no single answer or solution path</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>10. Recruit students from culturally diverse or underrepresented groups</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>11. Provide students with opportunities to participate in extra-curricular activities</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>12. Require students to complete community service</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>13. Provide counseling services for students’ social-emotional needs</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>14. Provide specialized counseling for students’ long-term career plans</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1. Administrators’ Median Responses to the Professional Culture Items (n = 205)
Curricular and instructional practices. Providing students with access to basic STEM resources, such as computers, Internet, graphing calculators, and laboratory equipment received a median importance rating of essential. All other items in this section had a median rating of either important or very important. On the Frequency scale, administrators reported providing access to basic STEM resources and providing access to visual and performing arts classes with a median frequency of every day. Items associated with program evaluation, faculty research, student participation in STEM competitions, and student shadowing of STEM professionals had a median frequency rating of once or twice a year. Approximately one third of the administrators reported never in response to requiring external program evaluation and promoting student participation in international STEM competitions. A number of the items in this section had a difference in median importance and frequency ratings, including internal program evaluation, student participation in national STEM competitions, and student shadowing of STEM professionals. Some discrepancies between importance and frequency ratings, such as participation in competitions, may be due to factors outside of the administrators’ control. Results of the curricular and instructional practices section of the survey are summarized in Table 2.

Figure 5 illustrates the percentage of administrators who responded to each of the curricular and instructional

<table>
<thead>
<tr>
<th>Item</th>
<th>Median Importance</th>
<th>Median Frequency</th>
<th>Median Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>15. Require preassessment of student knowledge in STEM classes</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>16. Require formative evaluation of student progress</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>17. Require summative evaluation of student progress</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>18. Require that the effectiveness of the specialized STEM program be internally assessed</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>19. Require that the effectiveness of the specialized STEM program be externally evaluated</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>20. Provide time for students to meet with research advisors</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>21. Promote faculty-based research</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>22. Provide students access to professional STEM journals</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>23. Provide students access to basic STEM resources</td>
<td>6</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>24. Provide students access to advanced STEM resources</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>25. Promote student involvement in national STEM competitions</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>26. Promote student involvement in international STEM competitions</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>27. Provide students access to visual and performing arts classes</td>
<td>5</td>
<td>6</td>
<td>-1</td>
</tr>
<tr>
<td>28. Provide students opportunities to shadow professionals in STEM fields</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>29. Offer students dual enrollment at local colleges or universities</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>30. Provide students opportunities to complete internships in STEM fields</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2. Administrators’ Median Responses to Curricular and Instructional Practices Items (n = 205)
practices items with a rating of either very important or essential. Providing basic STEM resources and requiring summative and formative assessment of students received the highest percentage of these ratings, while only about 25% of respondents rated promoting faculty research and requiring external program evaluation as very important or essential.

Policies and procedures. Only the Importance scale was rated in the Policies and Procedures section. Administrators gave a median importance rating of very important to all of the items in this section except for the item referring to providing students opportunities to obtain industry certifications, which had a median rating of important (Figure 6).

Teachers’ Survey Results

School climate. The median teacher importance rating for offering students tutoring or extra help in STEM courses and encouraging students to use their knowledge to better the world was essential. All other items in this section obtained a median importance rating of very important. Two of the School Climate items that were rated as very important but only enacted once or twice a year related to students’ meeting and collaborating with STEM professionals. Ratings for the School Climate items are summarized in Table 3.

Approximately four-fifths (80.8%) of the teacher respondents reported that it was very important or essential to offer students extra academic help if needed, while about half of the teachers responded with these highest two importance rating choices for working to enhance their schools’ reputations, providing opportunities for students to meet with diverse STEM professionals, and facilitating student collaboration with working STEM professionals. Figure 7 shows the percentage of teachers who rated each of the School Climate items as very important or essential.

Curriculum development and implementation. The median rating for designing real-world oriented curriculum was essential, with most other items receiving median ratings of very important on the Importance scale. Several items, including encouraging students to present products to authentic audiences, were rated as very important but only reported as occurring in practice infrequently (see Table 4).

Teachers rated most of the items in the Curricular Approaches section as very important or essential. Few (21.6%) rated adopting curricular units without
<table>
<thead>
<tr>
<th>Item</th>
<th>Median Importance</th>
<th>Median Frequency</th>
<th>Median Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Work to enhance and promote the reputation of excellence at your school</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2. Collaborate in STEM curriculum development</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3. Arrange collaborative projects for students with working professionals</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4. Expect students to maintain a professional lab</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>5. Offer students tutoring/extra help in STEM classes if needed</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>6. Offer guidance and counseling for student social/emotional needs</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>7. Celebrate student accomplishments, achievements, and awards</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>8. Encourage students to use their knowledge for the betterment of the world</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>9. Offer students opportunities to meet with STEM professionals of various backgrounds</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 3. Teachers' Median Responses to School Climate Items (n = 777)

<table>
<thead>
<tr>
<th>Item</th>
<th>Median Importance</th>
<th>Median Frequency</th>
<th>Median Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. Teach academic writing skills</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>11. Adopt preexisting challenging and advanced STEM units of study without making modifications</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>12. Modify preexisting challenging and advanced STEM units of study</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>13. Create challenging and advanced STEM units of study</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>14. Modify units to meet students' readiness levels</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>15. Emphasize depth of conceptual understanding of STEM topics</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>16. Design problem-based learning opportunities</td>
<td>5</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>17. Model making connections across and within STEM disciplines</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>18. Design curriculum that promotes real-world applications</td>
<td>6</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>19. Integrate controversial and/or timely STEM topics into class content</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>20. Require students to apply research skills to complex real-world problems</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>21. Teach research skills</td>
<td>5</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>22. Encourage students to select STEM research topics</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>23. Provide an opportunity for students to design and complete self-selected research project(s)</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>24. Encourage students to present products to authentic audiences</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>25. Provide explicit lessons to teach students to take notes effectively</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>26. Provide direct instruction to students on time management skills</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 4. Teachers' Median Responses to Curricular Approaches Items (n = 777)
modification in these highest two categories of importance. For the other items, the percentage ranged from approximately 50% to 80% of teacher respondents (Figure 8).

**Instructional strategies.** Teachers rated all items in the Instructional Strategies section as quite important, with all items receiving a median rating of either very important or essential. In terms of frequency, nearly all of the items in the section had a median frequency of at least once a week, except for encouraging student questioning, which had a median frequency rating of every day. No items in this section had a difference between the median importance and the median frequency of greater than one point. The largest percentage of teachers rated student questioning as very important or essential. This information is summarized in Figure 9.

**Learning environment.** In the section on Learning Environment, teachers only selected responses from the Importance scale options. The median rating for promoting a common vision of excellence at the school was essential, and directly instructing students on help-seeking behaviors was very important. The vast majority of teachers (83.8%) considered promoting a common vision of excellence for the school to be very important or essential, with a sizeable majority (70.7%) responding with one of the two highest importance ratings for providing direct instruction in seeking help. In contrast, fewer than half of the teacher respondents perceived promoting STEM careers over other careers (46.2%) or student articulation of long-term career plans (39.4%) to be very important or essential.
SUMMARY AND DISCUSSION

This study offered an exploratory description of the importance and frequency of various policies and practices in STEM-focused high schools in the United States. Items for the surveys were developed based on inductive analyses of common practices found in different types of STEM-focused high schools (e.g., selective, inclusive, and career and technical schools) with varied types of service delivery models (e.g., magnet, charter, school-within-a-school, comprehensive, and Governor’s schools). The purpose of the study was to gather a nationally representative sample of administrators’ and teachers’ perceptions about practices and policies to help identify and assess the critical components (Lynch et al., 2013) of STEM-focused education. This evaluative process led to the beginning stages of developing a descriptive framework based on the features unique to these specialized academic settings, which might inform future inductive and deductive studies, the creation of new STEM schools, and improvement of those currently operating (Scott, 2012).

Administrators rated three areas as essential: Provide students access to basic resources needed to engage in STEM-related research and projects (e.g., lab equipment, computers, Internet, graphing calculators, lab supplies); Provide students with opportunities to participate in extra-curricular activities; and Encourage teachers to ask open-ended questions with no single answer or solution path. Conversely, administrators perceived the items addressing faculty-based research, external program evaluation, and student participation in international STEM competitions to be relatively unimportant. A number of administrator items that were rated as very important were reported as occurring with low frequency, such as Recruit students from culturally diverse or underrepresented groups (e.g., females, African Americans, Native Americans, low SES; Provide time for students to meet with research advisors; and Provide students opportunities to complete internships in STEM fields.

Teachers rated importance and frequency quite high for most of the items on the teacher survey. Ten items received median importance ratings of essential from teacher respondents, 28 items had a very important median rating, and only three items had an important median rating. Across the four sections, the item with the highest proportion of very important or essential ratings on the STEM teacher survey was Encourage student questioning. It may indeed be somewhat alarming that 7% of teachers in the survey did not rate student questioning as very important or essential given the centrality of curiosity to scientific thinking and inquiry and literature on establishing inquiry-based teaching and learning environments (see Saunders-Stewart, Gyles, & Shore, 2012). The least important items to teachers were Adopt preexisting challenging and advanced STEM curricula without making modifications; Promote STEM careers over other career options; and Require written or oral articulation of long term career plans beyond undergraduate education. It is possible that these career-planning tasks do not reflect the missions of a majority of STEM high schools. Perhaps teachers are uncertain of how to provide such support or perhaps teachers feel that placing these unnecessary academic burdens on adolescents is exclusive of their roles as teachers. In either event, this perception is worth noting because of its disparity with the societal goal of increasing the number of students who pursue STEM-related majors in college and enter STEM-related careers.

Also of concern was that only 44% of administrators rated pre-assessment of students as very important or essential, suggesting that the perception of these students as a homogenous group may lead to homogeneous curriculum and instruction—failing to challenge the more advanced students and not providing appropriate scaffolding for those who may come to the schools less prepared. Another concern lies in the low importance teachers placed on student-selected research projects (only 58% rated this practice as very important or essential), and on STEM research projects and STEM current events (only about 55% of teachers rated these strategies as very important or essential).

LIMITATIONS

Several limitations influenced the findings of this study. First, the Importance scale appeared to have considerable ceiling effects for many of the items. Although it is not surprising that administrators and teachers would find many practices to be very important, research should continue to document which features are the most fundamental to high-quality STEM education. In future studies, researchers may obtain more variable responses by scaling responses without affixing anchor words such as important or essential to the scale points.

From the nearly 1,000 high schools to which we distributed surveys, 205 administrators and 777 teachers responded from 291 different schools. Because the response rate was not higher, it is reasonable to consider that those administrators and teachers who chose to respond may not have been fully representative of the entire population.
Perhaps administrators and teachers who were most enthusiastic or had the most available time were able to respond, which could create bias in the results. In short, a higher response rate could have strengthened the validity of our findings and increased the generalizability of our recommendations.

**RECOMMENDATIONS AND CONCLUSIONS**

As more STEM-focused schools and programs are developed, it is critical to systematically identify them and determine the impact they have on their students. The National Research Council (2011) established three broad goals for K-12 STEM education in the United States: expand the number of students who ultimately pursue advanced degrees and careers in STEM fields; expand the STEM-capable workforce; and increase science literacy for all students. Effective instruction and conditions and cultures that support learning (National Research Council, 2013) were identified as the two most proximal influences that should enable students to attain these goals. This study's findings indicated that teachers and administrators rated many related survey items as very important or essential, but the frequency of some practices did not match their perceived importance. These differences may exist because of barriers and limitations to implementing these practices in their respective schools, such as lack of time, materials, or teacher training. Future studies could investigate administrators' and teachers' perceptions about why the disparity occurs. In addition, the ways that schools address their effectiveness to fulfill their mission should be examined.

The next step is to determine the degree to which the factors identified as important and frequent affect student outcomes, and then to identify ways to support stakeholders in developing internal and external evaluation criteria for assessing their effectiveness in implementation. It is understandable that some schools may be required to follow mandated policies and procedures. Administrators and teachers at STEM high schools have indicated a variety of important aspects of the curricular, instructional, and environmental aspects of their schools. Analysis of the survey responses provided an overview of the state of STEM high schools in the United States. The administrator and teacher surveys in the present study are, in part, tools for assessing growth, which may inspire a continuous cycle of evaluation, reflection, and improvement.

**REFERENCES**


The Role of Challenge in Students’ Engagement and Competence in High School Science Classrooms: Hispanic and non-Hispanic Whites Compared

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ABSTRACT

This study explores the associations of ethnicity and perceived challenge with high-school students’ academic engagement and perceived competence in science. Data were collected through a variant of the Experience Sampling Method in which participants reported on their levels of engagement, perceived competence, and challenge while in science class, in response to signals from a vibrating pager. Hispanic and non-Hispanic White students reported similar levels of engagement in science, though non-Hispanic Whites reported higher levels of confidence. Results suggest that Hispanic and non-Hispanic White students respond differently to features of the learning environment. For example, while challenge was negatively associated with engagement in general, highly challenging science instruction had a less negative impact on Hispanic students’ engagement, and a positive impact on their perceptions of competence relative to non-Hispanic White students. Findings highlight the importance of studying students’ perceptions of their classroom learning experiences for understanding ethnicity gaps in STEM areas.

The purpose of this study is twofold: 1) to compare the engagement and perceived competence of Hispanic and non-Hispanic White students in high school science classes, and 2) to explore how ethnicity and perceived challenge may interact to contribute to students’ daily academic engagement and perceived competence in science classes.

The ethnicity gap in academic achievement between Hispanics and non-Hispanic Whites is particularly wide in fields involving science, technology, engineering, and mathematics (STEM). Hispanics have lower achievement in STEM courses, and as adults are severely underrepresented in STEM fields compared to non-Hispanic Whites.
(Taningco Matthew, & Pachon, 2008). Students of different ethnicities may respond to the same classroom learning environments differently. Certain features of the learning environment may be more engaging or enjoyable for one group vs. the other, or because of cultural differences, may be viewed as more or less important for one’s future. There could also be ethnic differences in students’ perceptions of competence for science that may help explain observed ethnicity gaps in STEM areas. Certain features of science learning environments may have differential impact on students of different ethnicities. Yair (2000) found that Hispanic students responded more positively than their non-Hispanic White counterparts to some features of learning environments.

Drawing upon the empirical and theoretical contributions of Mihaly Csikszentmihalyi (emergent motivation theory (EMT), 1990) this study focused on the role that academic challenge plays in influencing students’ engagement and perceived competence in science learning contexts. Specifically, we examine whether Hispanic and non-Hispanic White students differ from one another in terms of the relationship between challenge, engagement, and perceived competence. According to Csikszentmihalyi, challenge can be highly motivating, inviting deeper engagement in a task. As students take on appropriately challenging tasks, they experience a positive affective state, which leads them to engage more deeply and seek out similar challenges in the future. The relationship between challenge and engagement has been supported empirically: Generally speaking, as students perceive greater challenge in their learning activities, they tend to report greater levels of concentration and interest (Shernoff & Schmidt, 2008; Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). This type of engagement in challenge has also been shown to be related to longer-term persistence in academic pursuits (Shernoff & Hoogstra, 2001). In this paper we will examine the relationship between challenge and engagement in science among high school students.

A natural consequence of engagement with challenging academic tasks is that through this experience, students’ skills become enhanced. Successful interaction with challenge then, is presumed to deepen student engagement and build up a student’s competence and confidence (Csikszentmihalyi, 1990). While there are empirical studies showing the positive relationship between engagement and “objective” measures of competence such as grades (Alexander, Entwisle & Horsey, 1997; Marks, 2000; Voelkl, 1997), what may be more important, from a motivational perspective, is that students perceive themselves as competent. The perception of competence is a theme that runs through many of the most widely researched and accepted theories of human motivation (Bandura, 1989; Deci & Ryan, 1991; Eccles, 1983; Wigfield & Eccles, 2000). For example, Self Determination Theory (SDT, Deci & Ryan, 1991) posits that humans have a fundamental need to feel competent, and that this need directs much of human behavior. Feeling competent is motivating: when students believe they have the skill to accomplish a task, they are more likely to take on the task, will be more persistent in the face of obstacles, will be more likely to discard unproductive strategies, and will ultimately be more successful (Bandura, 1989; Eccles & Wigfield, 1983). An important task for educators then, is to help students feel competent. According to Bandura (1989), challenge plays a very important role in building up students’ competence and confidence: success in very low-challenge activities does little to make one feel more competent: the more meaningful (and motivating) successes are those in which one has had to overcome some moderate degree of challenge. Thus it is important to consider the relationship between challenge and perceptions of competence.

There may be individual differences both in students’ overall levels of engagement and perceived competence, and in the way that challenge is related to engagement and competence. For example, Shumow and Schmidt (2014) documented gender differences in both engagement and perceived competence in science. Further, they demonstrated that male and female students tended to react differently to challenge in science: While challenge resulted in increased engagement for boys, it resulted in decreased engagement for girls. These individual differences in students’ subjective experience in science are consistent with the long standing observed gender gaps in STEM pursuits in post secondary education and beyond. Given the ethnicity gaps that currently exist in STEM education and careers, it may be fruitful to examine the experience of Hispanic and non-Hispanic White students in high school science to determine whether there is variation by ethnicity in students’ engagement and perceived competence in science, and to determine whether students of different ethnicities respond differently to the experience of challenge in science. This type of exploration may provide some small insights into existing gaps in our postsecondary institutions and workplaces. Given the importance of response to challenge, engagement, perceived competence for academic success, understanding these individual

Role of Ethnicity and Challenge in Science Class 21
differences is critical to providing optimal learning environments for all students.

**METHOD**

**Setting and Participants**

Data were collected in 12 science classrooms – three classrooms each in regular-track general science, biology, chemistry, and physics. All classrooms studied were in a single comprehensive high school serving students from a diverse community located on the fringe of a large metropolitan area. The school serves 9th - 12th graders, with an enrollment of approximately 3,300. According to school records, 43% of students in the sample were eligible to receive free or reduced lunch. Hispanic students and students identifying as non-Hispanic White each comprised approximately 40 percent of the student body. While the sample for the larger study (Schmidt & Smith, 2008) included 244 students, the present study focuses on the 180 students characterized as Hispanic (n=85) or non-Hispanic White (n=95). The overall student participation rate across all classrooms was 91%, with half of the classrooms studied having 100% participation. Table 1 displays the demographic characteristics of the subsample examined in this study.

**Procedures, Instruments, and Measures**

Within each of the 12 classrooms, data were collected over two time periods (“waves”) during the academic year – once in fall and once in spring. For both waves, methods of data collection included traditional surveys, experience sampling techniques, and other methods not employed in the current analysis. Data from different sections of the same course were collected during the same time period so that the data collected from all 3 sections would represent the same point in the science curriculum, thus enabling analysis of the effects of particular content units while controlling for the effects of the instructor. Studying two different content units from each course reduces the possibility that findings regarding a particular course were idiosyncratic and entirely attributable to the specific unit examined.

During each wave of data collection, students’ subjective experience in each science classroom was measured repeatedly over a period of 5 consecutive school days using a variant of the Experience Sampling Method (ESM; Csikszentmihalyi & Larson, 1987). Participants wore a vibrating pager which was used to signal them unobtrusively using a remote transmitter at 2 randomly selected time points during each day’s science class. To minimize the disruption to class flow and maximize the variety of classroom activities recorded, the pool of participants in each classroom was divided in half, with each half following a different signal schedule. In response to each signal, students completed an Experience Sampling Form (ESF) in which they briefly recorded, among other things, their perceived levels of engagement, competence, and challenge. The ESF took approximately 1-2 minutes to complete. Each student provided up to 20 such responses, with the total number of responses being 3,229.

**Measures**

Engagement, perceived competence, and perceived challenge were measured by Likert-scale items (0=not at all, 3=very much) on the ESM self-report form. Engagement (outcome) was measured by taking the mean of three items where participants indicated how much they enjoyed, were interested in, and wished to be doing present activity (α=.76, M=1.27, SD=.51). Perceived competence

### Table 1. Sample Demographic Characteristics

<table>
<thead>
<tr>
<th>Sex</th>
<th>%</th>
</tr>
</thead>
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<tr>
<td>Male</td>
<td>53</td>
</tr>
<tr>
<td>Female</td>
<td>47</td>
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<tr>
<td>Race/Ethnicity</td>
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<td>non-Hispanic White</td>
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<td>35</td>
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<td>12th</td>
<td>2</td>
</tr>
<tr>
<td>N=180</td>
<td></td>
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</tbody>
</table>
Role of Ethnicity and Challenge in Science Class

(outcome) was measured by taking the mean of two items where participants reported on how skilled and successful they felt in the activity ($\alpha=.85$, $M=1.67$, $SD=.51$). Perceived challenge (level-1, momentary predictor) was measured by a single item where participants rated the challenge of the activity (single item, $M=.89$, $SD=.47$).

Participants reported on their ethnicity (level-2, person-level predictor) in a survey which was recoded such that 0=non-Hispanic White, and 1=Hispanic. Prior science achievement (level-2, control variable) was comprised of participants’ self reported grades in science prior to current year ($M=2.74$, $SD=.90$, range 0-4).

**RESULTS**

Simple Ethnicity Comparisons

Simple t-test comparisons revealed that the Hispanic and non-Hispanic White students in this study do not differ from one another in their overall levels of engagement, competence, perceptions of challenge, or prior science achievement. They do, however, differ in the degree to which they aspire to science-related jobs such that Hispanics are far less likely to aspire to science-related careers ($\chi^2 = 7.8$, $p<.05$).

Figure 1.  Engagement, Competence, and Challenge in Science by Ethnicity

Figure 2.  Prior Science Grades by Ethnicity
The Effect of Perceived Challenge on Students' Engagement and Perceived Competence, and the Role of Ethnicity on these Effects

Due to the nested nature of the data, with ESM reports (by students during classroom instruction) nested within students, Hierarchical Linear Modeling (HLM, Raudenbush & Bryk, 2002) was used to test the effect of perceived challenge on students' engagement and perceived competence, and the role of ethnicity on these effects, controlling for students' prior science achievement.

**Engagement.** Hispanic students did not differ from non-Hispanic Whites in mean engagement levels ($\gamma_{01}=.11$, ns). Higher levels of challenge were associated with lower engagement ($\gamma_{10}=-.25$, $p<.001$) for non-Hispanic White students. The negative effect of challenge on engagement was less pronounced (albeit marginally) for Hispanics than non-Hispanic Whites ($\gamma_{11}=.08$, $p=.052$). In other words, Hispanic students' levels of engagement were affected less negatively when they perceived science instruction to be highly challenging. The negative effect of challenge on engagement was also moderated by prior achievement ($\gamma_{12}=.03$, $p<.05$) such that students with higher prior achievement did not evidence the same negative relationship between challenge and engagement.

**Perceived competence.** Hispanic students reported lower levels of competence compared to non-Hispanic Whites ($\gamma_{01}=-.23$, $p<.05$). When science instruction was perceived to be more challenging, competence of non-Hispanic White students remained constant ($\gamma_{10}=-.14$, ns). Hispanics showed an increase in competence when science instruction was challenging, relative to non-Hispanic Whites ($\gamma_{11}=.13$, $p<.05$). (i.e., Hispanic students' ratings of competence increased when they perceived science instruction to be highly challenging. In comparison, non-Hispanic White students' competence ratings were not affected by challenging science instruction).

**DISCUSSION AND CONCLUSIONS**

Findings from this study provide important insights into the role that ethnicity and challenge play in high school students' feelings of engagement and competence in science.

Contrary to what is predicted by EMT (Csikszentmihalyi, 1990), challenge was negatively associated with engagement in this sample. A possible explanation for this finding might be found in the central principles of EMT—that students need to possess enough skill to successfully overcome the challenging tasks so that they feel more engaged in these tasks. In other words, students in this sample may not have felt skilled enough in the face of challenging science tasks which may have frustrated them and in turn may have resulted in decreased levels of engagement. The finding that prior achievement ameliorated the negative relationship between challenge and engagement supports this explanation. It is important, then, for teachers to provide students with challenging tasks appropriate to students' skill levels.

A second possible explanation for these findings has to do with the degree to which students value the tasks they are asked to do in science. According to Csikszentmihalyi (1990), in order for challenge to be motivating, the actor has to perceive some value in the challenging task. In recent research, Shumow & Schmidt (2014) found that students in this sample generally saw little value in their science activities. It could be that many students in the present sample did not respond to challenge by engaging, because they did not perceive the challenging activity as worthwhile.

Consistent with other research (Uekawa, Borman & Lee 2007; Yair, 2000), our findings suggest that Hispanic and non-Hispanic White students respond differently to
features of the learning environment. While Hispanic and non-Hispanic White students reported similar levels of engagement, our results showed that Hispanic students’ levels of engagement were affected slightly less negatively when they perceived science instruction to be highly challenging, relative to non-Hispanic White students. Following the same principles of EMT just mentioned, Hispanic students may have viewed their challenging science tasks as more valuable than non-Hispanic White students did, which might explain the less pronounced negative impact of challenge on engagement.

Further ethnic differences were observed in students’ ratings of competence both in general and in relation to challenge. In general, Hispanic students reported feeling less competent in science class than non-Hispanic White students. When science instruction was perceived to be more challenging, however, Hispanic students reported increased levels of competence, as opposed to non-Hispanic White students whose competence remained constant. This suggests that challenging science instruction can be especially beneficial for Hispanic students’ feelings of competence in science class.

Given the reality of the ethnicity gap in science achievement and STEM occupations, our findings are very promising because, as reviewed earlier, several theories of human motivation suggest that higher perceptions of competence in any given task is a critical factor in continued success and persistence in that task. Thus, providing challenging tasks may be one way to improve Hispanic students’ perceptions of competence in science class, which may then lead them to seek more careers in STEM fields in the future. Alarmingly, however, we observed that the teachers tended to assiduously reduce the challenges in the science classes with high numbers of Hispanic students, believing that the students were overwhelmed by science (Shumow & Schmidt, 2014). It is important for science teachers to understand the counterproductive nature of that tendency.

Together, these findings highlight the importance of studying students’ perceptions of their classroom learning experiences for understanding ethnicity gaps in STEM areas. Future studies aimed at understanding the socialization practices that contribute to the Hispanic students’ responses to challenge are warranted and could uncover pathways to increase the number of Hispanic students seeking to study and pursue STEM careers.

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Innovation and STEM Schools

by Julia Link Roberts, Ph.D.

What words come to mind when thinking about innovation? Today, technology may be one of the first thoughts as technological innovations readily make the news. Another thought about innovation may be linked to entrepreneurship or creativity. “The success of the United States in the 21st century – its wealth and welfare – will depend on the ideas and skills of its population (President’s Council of Advisors on Science and Technology, p. 1). Innovation is key to a bright economic future.

How do schools with a focus on science, technology, engineering, and mathematics (STEM) fit in with state goals to increase innovation and to boost the economy? “STEM-focused schools represent a unique National resource, both through their direct impact on students and as laboratories for experimenting with innovative approaches.” (President’s Council of Advisors on Science and Technology, p. 14). These schools are certainly a unique national resource, and they offer outstanding opportunities to nurture young innovators. Although developing young professionals who will have the capacity to innovate must be intentional – it will not just happen.

So the question arises: In what ways do educators encourage creativity and innovation? A clear way to do so is to include creativity on the rubric for student products. “Unless teachers clearly state that they expect and will honor creativity, they are not likely to see creative approaches to products or various perspectives in viewing the content (Roberts, 2014, para. 6).” The Developing and Assessing Product (DAP) Tool (Roberts & Inman, 2015) includes creativity as one of the four components for assessing all student products. Students are challenged and expected to present the content in a new way or with a different perspective as well as to express creativity in the product they develop.

Another way to encourage creativity is to ask lots of questions that do not have right answers. Having a storehouse of information is very important, yet creative thinkers will develop the capacity to problem solve using that valuable information. Classrooms and laboratories that encourage looking at phenomena in various ways will provide the culture and background that encourages creativity and, therefore, sparks innovation.

Of course, students must have a strong content background in order to think creatively about the content. An interdisciplinary focus is often key to innovation. That interdisciplinary perspective can come from one individual or from a team representing various disciplines. A variety of vantage points stimulate creative responses to a problem or question. Sparks of innovation come from thinking about ideas (content) in new ways. Creative problem solving is something to start early and to continue throughout a student’s education. Initially, some students will be not comfortable with problem-solving as there is not one right answer. Students may not have experienced taking risks (not knowing the right answer). Scientific discovery emanates from a question for which the “right answer” is not yet known, and perhaps there will be several possible solutions rather than a single right answer. Innovation comes from keeping the mind open for possibilities. New ideas come from staying open to the unexpected. Think of the discovery of penicillin and graphene.
Innovation is important to the economy of our states and nation. It is useful to know how your state measures up on the New Economy Index. Those data can help in spreading the word about the immediate and long-term impact students at your school can make in economic development, and they can be valuable sources of information when advocating for your school or for STEM education in general. A website for obtaining rankings on the Innovation Index is [http://www.itif.org/publications/2014-state-new-economy-index]. Categories on which states are ranked in this index are knowledge jobs, globalization, economic dynamism the digital economy, and innovation capacity.

“Innovation requires highly able, determined, and creative leaders and thinkers (National Science Board, p. 7).” Specialized STEM schools play an important role in educating young people as promising professionals who have the potential to be innovators today and in the future.

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A review of “Enhancing Adolescents’ Motivation for Science: Research-Based Strategies for Teaching Male and Female Students” by Jennifer A. Schmidt and Lee Shumow, Corwin, 2013, $27.95.

Reviewed by Julie Esparza

In Enhancing Adolescents’ Motivation for Science: Research-Based Strategies for Teaching Male and Female Students, Jennifer Schmidt and Lee Shumow provide a guide for motivating students in science classrooms. Drs. Schmidt and Shumow are professors in the educational psychology department at Northern Illinois University. For several years they have studied science classrooms in high and middle schools by collecting data through observing classrooms, video-taping lessons, interviewing teachers, and surveying students. This book, written in engaging, everyday language, serves as a means to share their research findings with science teachers. Research aside, the finesse of their writing demonstrates these authors to be teachers of teachers.

Enhancing Adolescents’ Motivation for Science devotes an entire chapter to one of nine different motivational concepts: value, affiliation, autonomy, confidence, success, goal-orientation, ability beliefs, challenge, and emotion. The layout of each chapter assists the reader to conceptualize the information in a variety of ways by using anecdotes, descriptions, research citations and classroom examples. While the intent of this book was to help science teachers improve student motivation, this book would be useful to any teacher of adolescents. The sections of each chapter are written simply and to the point, which allow the reader to grasp the information quickly.

Each chapter begins with an anecdote that not only illustrates the main point, but entertains. The authors share real examples from their lives and research that effectively demonstrate the motivational concept. Many of the scenarios include the voice of the subject. Quotes from students and teachers add depth to each story. The concept embedded in the anecdote is then described and set in a classroom context, furthering the reader’s understanding of the characteristic.

Research findings follow, especially differences related to gender. This includes citations from experts and seminal studies related to the motivational characteristic. Lending credibility and importance to the subject, it allows the teacher to understand and communicate the research behind their choices. Arming teachers with evidence is helpful during a time when teacher actions are being analyzed through evaluation methods like the Danielson Model.

Next, the authors and describe how teachers may implement the strategy for the students in their science classrooms. Most of each chapter focuses on “how-to” implement the concept with practical suggestions like, “have students reflect on the usefulness of what they are learning,” or “use story-telling.” Many suggested actions may seem common-sense and second-nature to effective teachers, but this book assists the reader to connect the action to the motivational construct: why it is important, it’s proven effectiveness, and the intended effect on student learning.

Each chapter concludes with a resource section including NIU’s website Internet address. There the reader will find video clips, additional read-
ing for teachers, resources to be shared with parents, and links to additional outside resources. The resources there echo the main points of each chapter and give teachers additional practical tools to support their instruction.

At a time when society is in need of members with a strong science background, this book is a tool for teachers who are responsible for furthering the interest and skills of their science students. Grounded in research and practical ideas, this easy-to-read book is a welcome addition to the library of science teachers.

Julie Esparza is Gifted and Talented Program Coordinator in West Aurora (IL) School District 129.
“Analyze, Acquire, Apply, and Write”
as a New Learning Model in Science
by Jeong V. Choe, Ph.D.

ABSTRACT

I have developed a new teaching and learning model called AAAW, which stand for Analyze, Acquire, Apply and Write. This model grows from action research and unique experience in teaching a biochemistry course to high school students who are talented in math and science. In this model, students first “Analyze” lab data to generate questions that lead them to “Acquire” background knowledge. Students then go back to the data and “Apply” their new knowledge to better understand the data. Finally, students “Write” about the connections they make from their reading, data analysis, and application of the data. The rationale behind how the AAAW model was developed will be shared in this paper.

Designing and teaching a high school biochemistry course is a unique and challenging experience because biochemistry is typically offered as an advanced elective in college. College students will have taken general and organic chemistry, as well as other advanced science prerequisites prior to taking their biochemistry course. Instead, the biochemistry class that I have been teaching for the past six years is one of the elective courses offered to juniors and seniors at the Illinois Mathematics and Science Academy (IMSA), a residential high school for students who are talented in math or science. Even though the students enrolled in Biochemistry have an aptitude for math and science, they generally have a wide range of chemistry and science backgrounds. The prerequisite for Biochemistry is only a semester-long sophomore chemistry core course, which means that there can be seniors in the elective who have not taken a chemistry course since the first semester of their sophomore year. Conversely, there are students in Biochemistry who have taken many chemistry electives offered including two semesters of advanced chemistry (equivalent to a college general chemistry course), two semesters of organic chemistry, as well as advanced biology courses that touch on related molecular topics.

To accommodate the diverse student background in Biochemistry, I have developed a learning model called AAAW, which stands for Analyze, Acquire, Apply, and Write. In this model, students first “Analyze” lab data to generate questions that lead them to “Acquire” background knowledge. Students then go back to the data and “Apply” their new knowledge to better understand the data. Finally, students “Write” about the connections they make from their reading, data analysis, and application of the data in the context of current research in the field. I have implemented this learning model to an online biochemistry course and teacher resource material, which will be mentioned later. I have also designed the logo as shown in (Figure 1) in which all four letters are embedded in the image.

Figure 1. A logo for AAAW learning model, which stands for Analyze, Acquire, Apply, and Write.
The rationale behind how I have developed this model stems from the five initial design elements of the course that I created to help to give students skills and knowledge they need to be successful in the class regardless of their previous chemistry experience. First, I designed practice problems to review previously learned topics and skills, which were especially focused on transfer skills. Often students experience a difficult time transferring their learning to another context. The study I have done shows that a positive effect can be demonstrated in student performance on the unit exam after having them practice transfer skill (Choe, 2014). The practice included spending instructional time in analyzing practice problems in a systematic way and making connections between and within concepts. For example, when students learn about the overarching concepts of equilibrium, they are guided to make connections between different topics that are related to it including osmosis, buffer, and amino acid titration. This is accomplished by providing the students with sets of carefully designed guiding questions that are designed to help them make connections between the topics.

Second, I added more structure to the class by dividing the course into five units that cohesively flow from small to large molecular structures, starting with Water and Equilibrium, Amino Acids to Protein, Protein Structure and Function, Enzyme Kinetics and Inhibition, and finally ending the course with Metabolism (Table 1). The logic behind the sequence is to have students start the course with concepts that are related to the last unit of their introductory sophomore chemistry course, which is equilibrium and acid-base chemistry. This design makes taking the biochemistry course more equitable to the students whose only experience is the introductory chemistry course as opposed to those who have taken multiple chemistry and biology elective courses prior to entering biochemistry. Also, this sequence helps the course to be more coherent as it builds from smaller to larger molecular structures, going from amino acids to proteins, and then to protein function, such as enzymes.

Third, for each unit, students are required to come prepared to class with some background knowledge from the textbook. I provide students with reading questions for guidance and then go over the material in class. Table 2 shows some sample questions from the first unit, which is the one on Water and Equilibrium. I find this method to be more effective than lecturing because students are more engaged in the discussion. From time to time, students are asked to present specific sections of the reading to classmates.

Fourth, students collect and analyze data to look for trends, resulting in learning through inquiry. Examples of student data from titration of amino acid lab and a sample of guiding questions are provided are shown in Figure 2. These questions help to focus the activity so that the students can draw conclusions and build their understanding of concepts. This practice immerses students in the authentic practice of science, which aligns well with the Science Practice Standards from Next Generation Science Standards (NGSS, 2013).

Lastly, I created supplementary multimedia videos that reinforce class concepts so students can review and study on their own time. As this generation of students regularly uses their mobile devices to access information, I created videos specifically for my students to enhance their classroom learning and reinforce the concepts. All students, especially those with learning differences, expressed that they were able to review the materials at their own pace by playing and pausing as needed as they were reviewing the materials outside of their classroom environment. My students as well as others were frequently using these biochemistry multimedia videos. For instance, one of the unedited vid-

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**Figure 2.** A sample of student data on titration of amino acid lab and guiding questions that are provided to the students.
| Unit 1: Water and Equilibrium | 1. Apply molecular structure of water to thermal and solvent property of water  
2a. Relate equilibrium to osmosis  
2b. Apply the concept of the water molecule and osmosis to solve problems.  
3. Relate equilibrium to buffer. |
| --- | --- |
| Structure and Properties of Matter: HS-PS1-3  
Stability and Change: HS-PS1-6  
Analyze and Interpreting Data: HS-PS2-1  
Constructing Explanation: HS-LS1-3 |
| Unit 2: Amino Acids to Protein | 1. Build background knowledge on structure of amino acid and examine how amino acid structures influence their properties  
2. Understand amino acids as building blocks of proteins and how they play role in different levels of protein structure |
| Structure and Properties of Matter: HS-PS1-3  
Organization for Matter: HS-LS-6  
Structure and Function: HS-LS-1, HS-LS1-2  
Using Computational Thinking: HS-LS2-1  
Developing and Using Models: HS-LS1-4, HS-LS1-5, HS-LS1-7  
Analyze and Interpreting Data: HS-PS2-1  
Obtaining, Evaluating, and Communicating Information: HS-PS4-5 |
| Unit 3: Protein Structure and Function | 1. Relate structures of proteins to their functions  
2. Use protein technology tools to isolate, purify, and analyze structure of protein |
| Organization for Matter: HS-LS-6  
Structure and Function: HS-LS-1, HS-LS1-2  
Analyze and Interpreting Data: HS-PS2-1  
Planning and Carrying out Investigations: HS-LS1-3  
Obtaining, Evaluating, and Communicating Information: HS-PS4-5 |
| Unit 4: Enzyme Kinetics and Inhibition | 1. Use data and Michaelis-Menten and Lineweaver-Burk plot models to analyze enzyme kinetics  
2. Classify enzyme inhibition into competitive, uncompetitive, and mixed inhibitors  
3. Apply enzyme kinetics and inhibitions to medicinal drugs |
| Chemical Reaction: HS-PS1-4, HS-PS1-5  
Analyze and Interpreting Data: HS-PS2-1  
Planning and Carrying out Investigations: HS-LS1-3  
Obtaining, Evaluating, and Communicating Information: HS-PS4-5 |
| Unit 5: Metabolism | 1. Make connections between metabolic cycles |
| Definition of Energy: HS-PS2-1, HS-PS2-2 & HS-PS2-5  
Energy in Chemical Process: HS-PS3-3 & HS-PS3-4  
Chemical Reactions: HS-PS1-2 & HS-PS1-7  
Developing and Using Models: HS-LS1-4, HS-LS1-5, HS-LS1-7  
Constructing Explanation: HS-LS1-3 |

Table 1. Structure of the biochemistry course provided by the five units
“Analyze, Acquire, Apply, and Write” as a New Learning Model in Science

Table 2. Sample Reading Questions from Water and Equilibrium Unit

<table>
<thead>
<tr>
<th>Topic</th>
<th>Sample Reading Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Properties of Water</td>
<td>a. Describe the intermolecular structure of ice, liquid and vapor. Also, discuss how many percentages of molecule form hydrogen bonding.</td>
</tr>
<tr>
<td></td>
<td>b. Human may eliminate as much as 1200 g of water daily in expired air, sweat, and urine. The associated heat loss may amount to approximately 20% of the total heat generated by metabolic processes. How is this possible?</td>
</tr>
<tr>
<td>Solvent Properties of Water</td>
<td>Water is ideal biological solvent. It easily dissolves a wide variety of the constituents of living organisms.</td>
</tr>
<tr>
<td></td>
<td>a. Describe hydrophilic molecules:</td>
</tr>
<tr>
<td></td>
<td>b. Describe hydrophobic molecule (Water Hating):</td>
</tr>
</tbody>
</table>

eos I quickly created on Amino Acid Titration for my students, http://www.youtube.com/watch?v=T-wa0LiKCre, gained thousands of viewers in a year.

What other challenges do we face as educators as technology advances? I have noticed a couple of shifts among the way my students learn. Students are spending more time acquiring their knowledge from electronic and mobile devices rather than from textbooks. Also, they score better on quantitative type questions on their assessments compared to qualitative type questions (Figure 3). This result shows that there is a need for my students to improve their explanation skills. For instance, my sophomore students from Introductory Chemistry Course-Scientific Inquiries in Chemistry (SI Chemistry) offered during Spring 2013 demonstrated a test average of 92% when the assessment was primarily focused on their quantitative skills compared to 76% as the focus shifted to assessing their qualitative skills (p < 0.05). The assessment that measured students’ quantitative skills was based on the Stoichiometry unit and the assessment that measured their qualitative skills was based on the Equilibrium and Acid-Base Chemistry unit. In the Biochemistry elective, the gap between student performance on the quantitative and the qualitative scores on the unit exams decreased by 5%. Although there may be a limitation in comparing student performance from two different courses, students enrolled in the Biochemistry elective still did significantly better on the unit test on Enzyme Kinetics, which was quantitative in comparison to the unit test on Protein Structure and Function, which mainly required qualitative reasoning. The average on the Enzyme Kinetics unit test was 92% as opposed to 81% on the Protein Structure and Function test. While the difference is still significant, the decrease in the gap between the qualitative and quantitative exam scores may be due to self-selection in that students who have done well on chemistry or biology tend to take the biochemistry course. This difference in their performance is shown in Figure 3.

![Average Unit Exam Score Comparison](image)

**Figure 3.** Student performance on quantitative versus qualitative based test in two courses, Scientific Inquiries in Chemistry and Biochemistry offered during spring semester of 2013, significant at the p<0.05 level.

Due to the strong need that I see in my own students to improve their ability to learn and explain qualitatively, I started including more writing pieces that required students to explain their understanding. This also led to designing an online biochemistry course.
course where students are guided to make connections and explain through writing. This type of a writing-focused course may not be a typical setting for a science class and it may be more challenging to engage students without being face-to-face. However, computer-mediated communication can encourage more distributed participation and equitable discussion (Swan, 2002). This could mean that the online biochemistry course can be a place for students to write to learn and improve their skills in explaining their understandings qualitatively. If designed well, even the introverted students who may not typically participate in verbal discussions and/or the students that may dominate the discussion could more equitably contribute their thought process and gain from feedback on the topics covered.

In my experience described previously, students in the biochemistry elective need to improve their qualitative learning. This need, in conjunction with the five design elements of the biochemistry course, led to development of a one-semester online Biochemistry course to implement AAAW model. This course addresses fundamental concepts in chemistry, such as Equilibrium, Acid-Base, and Kinetics that addresses chemistry in the context of biology. The content includes: 1) applying equilibrium process to study biochemical reactions as well as cell structure, 2) studying the structure and function of amino acids and proteins, and 3) analyzing the kinetic parameters of enzymes including different mechanisms of how drugs are used to inhibit enzymes. The course is similar to my traditional course (Table 1) except Metabolism is not included in the online version. That is because the extra time that is originally designed for learning about connections in metabolism in biochemical pathways is spent in writing about making connections, and applying, and transferring the learning to literature articles. The online course is designed for non-IMSA students who do not have access to a biochemistry course in their schools. Also, this online offering can be used by teachers who are interested in adapting the AAW model or in need of a resource to develop units in amino acids or protein, and/or to design a high school biochemistry course.

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Learning Outcomes</th>
<th>Learning Model, Content, Process</th>
<th>Assessments</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-1</td>
<td>Analyze</td>
<td>*Student will be analyzing the data from the titration of amino acid lab</td>
<td>*Assess student ability to make observation and generate questions on titration of the amino acid lab.</td>
</tr>
<tr>
<td>2-2</td>
<td>Acquire</td>
<td>*Students will acquire knowledge on basic structure of amino acids. *Students will acquire background knowledge on how amino acid can be in protonated and deprotonated form based on the buffer condition it is placed in.</td>
<td>*Assess student ability to acquire background knowledge and answer questions about the structure of amino acids.</td>
</tr>
<tr>
<td>2-3</td>
<td>Apply</td>
<td>*Apply the background acquired to further analyzing the data *Students will be solving problem</td>
<td>*Quiz: Assess student ability to solve amino acid and buffer problems</td>
</tr>
<tr>
<td>2-4</td>
<td>Write</td>
<td>*Apply concept of buffer and amino acid titration to a research article, a case study of a patient experiencing imbalance and acidosis in the blood buffer system.</td>
<td>*Writing Assignment: Assess students ability to make connections between concepts and write their own review article</td>
</tr>
</tbody>
</table>

Table 3. A sample of how AAAW is used in one of the units on Equilibrium in Amino Acids
The online biochemistry course is built on the Analyze, Acquire, Apply and Write (AAA W) model that I developed. A sample of AAAW model for one of the units on Equilibrium in Amino Acids is shown in Table 3. The online course, similar to the original course (Table 1), consists of the following five units in order: Water and Equilibrium, Equilibrium in Amino Acids, Amino Acid Structure and Function, Protein Structure and Function, Enzyme Kinetics and Drug Inhibition. The main difference is that the online version is writing-focused and follows the AAAW model.

As I created and used the AAAW model for my online biochemistry course, I wanted to outline the goals clearly for both teachers and/or students in each unit to avoid any confusion (Figure 4). I also tried to address the following question in my course design: How can the online biochemistry course be effectively used either by students or teachers of students who have been exposed to digital media their entire lives? This question was addressed by adding interactive pieces such as having students write data-driven analyses (Figure 5). Students are also asked to share their analysis before they move onto the next step, which serves as a personalized learning space for each student as they write about their own analysis of the data, explanations of their understanding and connections they make as well as others. This model also may help teachers who are used to traditional ways of teaching to adapt to changes in how students learn and process information. It has become more important that students express their understanding as they have tendency to passively gain...
understanding through online materials rather than integrating knowledge and expressing qualitatively. I offer the AAAW model as one of the data-driven ways to promote student writing in science classes. This is accomplished as students initially start with data analysis, then acquire concepts that allow them to go back to the data and further apply their understanding. I hope deeper understanding of concepts occurs as students write about connections they make during the AAAW processes.

ACKNOWLEDGEMENTS

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REFERENCES


“Analyze, Acquire, Apply, and Write” as a New Learning Model in Science
The Complexity in Defining Leadership: How Gifted Students’ Backgrounds Influence Their Understanding of Effective Leadership

by Shawon Jackson, Satoe Sakuma, Dr. Purva DeVol

ABSTRACT

There is no universally accepted definition of what it means to be an effective leader. Individuals understand leadership differently based on their own identities and lived experiences. The purpose of this investigation is to determine how one’s ethnicity, class, and gender identities influence their understanding of effective leadership, focusing specifically on gifted and talented eleventh and twelfth grade high school students at residential academies in the United States. The results show that there is a significant relationship between one’s race/ethnic and class background and their understanding of what it means to be an effective leader. From this, we argue that gifted and talented students are able to develop a greater understanding of how to be an effective leader in their communities, high schools, and workforce by participating in leadership education programs that take advantage of the multiple perspectives on leadership present in their own school.

Key Terms: Leadership, students, minority, African-American, Hispanic

INTRODUCTION

Leadership is a complex topic, which, to date, still has no concrete definition. For this reason, different people will perceive leadership in very unique ways. The perception of what traits and behaviors define a leader seems to derive from one’s cultural upbringing. Scholarly research suggests that there is a strong connection between culture and leadership (Parry, 2001). More specifically, one can argue that leadership and culture are directly related, and each has a profound impact on the other. More specifically, an effective leader has a great impact on his or her surroundings, just as his or her surrounding cultures influence their effectiveness as a leader. (Parry, 2001).

One of the difficulties with this research is that “there is no reasonable agreement on what traits or behaviors are leadership traits of behaviors.” (Barker, 1997). Barker introduced the expansive definition of leadership that differs among groups of people. He studied various viewpoints of leadership such as “The Social Construct of Leadership, Leadership as an Ability, Management as an Ability, Leadership as a Relationship” and “The Process of Leadership.” (Barker, 1997). Through this investigation Barker concludes the “need to conceptualize leadership in a different way, and come to a more common understanding of what it is.” Keith Grint (2005) also struggles in defining leadership in concrete terms, studying leadership as a position, results, process and person. Studying the factual evidence that conclude positively for each area of leadership, there are also negative results. Grint claims that: “Leadership remains an essentially contested concept.”

In 2003, over 26,000 articles could be found related to leadership in the Expanded Academic Database, (Winston and Patterson, 2005). The fault of many of these studies is due largely to the
lack of examining leadership as a whole, but instead studying only parts of leadership. Compiling 160 articles and books containing definitions of leadership, Winston and his team members integrated the definitions.

The perceptions of the qualities of leadership vary depending on the observer. According to Dr. Mumford (2000) at the University of Oklahoma, creative problem solving, social judgment skills and knowledge are the necessary traits to becoming a successful leader. Creating a model to demonstrate the flow of leadership characteristics on leader performance, it includes traits such as career experiences, motivation, personality, and environmental influences. Although knowledge is an important factor, a leader must “indicate that these skills represent unique capacities reflecting something above and beyond general intelligence.”

This differs from the result of the study performed by Dr. Karen Orvis (2010), which identified “four primary instructional design attributes that serve as key determinants of a self-development activity.” The four attributes are content relevancy, learner engagement, challenge and structure. Content relevancy “is the degree to which the instructional content… directly addresses specific knowledge or skills in need of development” (Orvis, 2010). This concept overlaps with Mumford’s view of social judgment skills, whereas traits such as learner, engagement, challenge and structure introduces a new plane of leadership qualities. Learner engagement refers to the reflection of stimulating individuals to be “mindfully engaged in the process of building, practicing, evaluating, and applying the capability to be mastered.” (Orvis, 2010) This also shows relates with Mumford’s view of motivation. However, challenge and structure are not discussed by Mumford whereas Orvis does not include personality or environmental influences in her definition of leadership.

Although there are similarities between studies on defining leadership, “beyond communication and interpersonal skills, however, youth leadership remains a fuzzy concept in the literature.” (Conner, 2007) Amy Bisland would argue that students need to be educated in the leadership characteristics “such as kindness, intelligence, problem solving, communication, cooperation, honesty, fairness, and confidence.” (Bisland, 2004)

Contemporary researches have leaned toward emphasizing the actions of leaders instead of studying their traits. “Warren Bennis and Burt Nanus have enlarged the definition of leadership to include more than just doing things right;” they claim that the difference between managers and leaders are that leaders “do the right thing.” Their list of characteristics include, establishing and maintaining visons, maintaining visible presence, and maintaining positive interpersonal relationships. (McEwan, 2000) Both Bisland and Bennis introduce new concepts to the already unclear vision of leadership. Honesty, fairness, “the right thing” all portray the need for a leader to be ethical. This is not mentioned in either Mumford or Orvis, which indicate the Venn diagram-like structure the views of leadership can be corresponded to. All the researchers listed above thoroughly discuss the importance of communication skills and intelligence. Beyond that, their ideas sprout in different directions.

For this reason, we seek to find the differences in leadership perception and style between various ethnic groups. Our research reveals that leadership education programs should acknowledge and take advantage of the distinct ways in which students perceive effective leadership based on their ethnic backgrounds. Utilizing this diversity of thought will help all students develop a more comprehensive understanding of leadership.

**MATERIALS AND METHODS**

A total of 232 eleventh and twelfth grade students from five residential math and science focused schools in the United States participated voluntarily to complete a survey. The survey consisted of eight questions (see Appendix).

The first question asked the students to list three traits they believed were important in becoming a successful leader. The second question asked to rank those three traits listed in question one from most important to least important. These traits demonstrated the leadership skills that the students could recognize. Text analysis was used to analyze this data. This provided the information of grouping similar traits together such as “articulate” and “good communicator.”

In the third question, the students were asked to select five traits given a list of eighteen traits that were most commonly listed as traits of leadership in scholarly articles (including charismatic, articulate, confident, adaptable, stable, goal-oriented, and conscientious), and some traits commonly associated with leadership, but not listed in the scholarly articles (including humorous, witty, bilingual, honest, ethical, tall, fluent English speaker, sociable, well-groomed, diplomatic, and demanding). The fourth question involved two scenarios that ultimately distinguished the students who believed ethics was involved with leadership from the students who did not. These questions were analyzed by using cluster analysis, which focused on what traits the students with different races tended to choose. This differentiated the students by race and also by the skill sets of leadership they recognize.

The fifth through the eighth questions asked for the demographic and family information of the students, including gender and highest level of parental education. The categories for race are taken from the U.S. Office of Management and Budget’s standards for collecting and tabulating data on race and ethnicity.

After obtaining institutional review and administrative approval
at each school, the surveys were electronically delivered. The students were given approximately two weeks to return the survey. LimeSurvey, an Open Source web application to develop, publish and collect survey responses, was used to collect the survey data. For our data analysis, we clustered the leadership traits into fourteen different groups (see Appendix) to see if certain groups of students – based on race, gender and family education level – chose traits from one group over another.

When analyzing results, we omitted responses in which 5% or less of the students chose a given trait. We also did not analyze the responses of groups (e.g. specific racial sub-groups) that had less than a 5% representation relative to the entire surveying population. Also, the family member who attained the highest educational degree determined family education level. Lastly, for the purposes of this study, African-American and Hispanic students were categorized collectively into one minority group, as both of these groups are largely underrepresented at math and science academies.

RESULTS

After running a Likelihood-Ratio Chi-Square test, we found no significant relationship between the following groups: race/ethnicity and what students view as the least important trait in a leader (df=14, p=.294); gender and what students viewed as the most important trait in a leader (df=5, p=.889); gender and whether or not students consider ethics when deciding leadership effectiveness (df=1, p=.653); family education and what they view as the most important trait in a leader (df=15, p=.171); and family education and whether students consider ethics when deciding leadership effectiveness (df=3, p=.725).

However, the same statistical test revealed a correlation between the following: race/ethnicity and what students believe the most important trait in a leader is (df=10, p=.048); race/ethnicity and whether students consider ethics when deciding leadership effectiveness (df=2, p=.014); and family education and what students consider to be the least important trait in a leader (df=21, p=.049).

Whites tended to consider ethical behavior as a core trait in an effective leader. Minority groups tended to favor communication and self-drive as the top traits needed for an effective leader. Asian students recognized overall confidence as the number one trait in an effective leader. Students from a family where neither parent earned a college degree did not recognize physical traits as being the least important trait within a leader. Instead, the most common trait recognized by this group as least important was “witty.”

Figure 1 shows the number of Asians, Minorities and Whites that chose a leadership trait from a given group as being the most important quality in an effective leader. Figure 2 shows the number of participants per race that considered ethical behavior when determining the effectiveness of one's leadership. Figure 3 shows the relationship between family education level and the trait he or she selected as the least important in terms of leadership effectiveness.

Figure 1. Race/Ethnicity versus Perception of Most Important Leadership Trait

Figure 1. This graph shows the number of Asians, Minorities and Whites that chose a leadership trait from a given group as being the most important quality in an effective leader. 43 Asians’, 17 Minorities’ and 141 Whites’ responses were analyzed, totaling 201 responses. To know which traits are categorized in which groups, please refer to the Appendix.
DISCUSSION

With the cumulative differences in leadership perceptions between the groups, we can proceed to think about the implications of this study. One application is of our research is leadership training. Previous research indicates that educational leadership is an integral role in the success of effective schools (Bosker, Kruger, Witziers, 2003). However, leadership education programs are often missing from the high school curriculum. Our research indicates that a student’s ethnic and class background has a strong influence over their understanding of leadership. Without leadership education programs, students’ perspective on leadership may remain limited based on their ethnic and class backgrounds. To be sure, students may expand their understanding of leadership in the classroom or through extracurricular activities. But that is not guaranteed. With leadership training programs that intentionally foster dialogue amongst students from different backgrounds, students can develop a more nuanced view of what effective leadership entails.

Figure 2. Percentage of Students Who Consider Ethnicity When Determining Leadership Effectiveness

Figure 2. This shows the percentage of participants per race that considered ethical behavior when determining the effectiveness of one’s leadership. 43 Asians’, 18 Minorities’ and 143 Whites’ responses were considered, totaling 204 responses.

Figure 3. Family Education Level versus Perceived Least Important Leadership Trait

Figure 3. This graph shows the relationship between family education level and what trait he or she selected as the least important in terms of leadership effectiveness. A total of 163 responses were analyzed, 18 of whom live in a family where the highest degree earned is an associate’s degree, 47 where the highest degree earned is a bachelor’s degree, 83 where the highest degree earned is a graduate degree, and 15 where no member earned a college degree.

CONCLUSION

Amongst gifted and talented students at residential math and science academies in the United States, there is a clear relationship between one’s race/ethnic and class background and their understanding of effective leadership. This diversity of thought is important, and leadership education programs should be implemented that encourage students to discuss these differences. Consequently, students will be able to expand their perspective on leadership. In this way, a student’s understanding of leadership will not be limited based on their personal identities. Instead, they will be able to combine their unique perspective on leadership with that of others, in order to more fully define what effective leadership means.
APPENDIX

Survey Administered to Junior and Senior Students:

Consent Statement:

The purpose of this survey is to determine how gifted students at math and science academies across the nation view leaders. More specifically, we are interested in learning which traits and skills each student believes to define an effective leader. Note that you are not by any way forced, or required, to take this survey, and you may stop at any time. The survey is completely voluntary, anonymous, and is of minimal risk. If you do choose to participate in this survey, then you understand that your information to be shared with outside parties for a research investigation. Furthermore, by taking this survey, you commit to waive your written consent, given that this survey is of minimal risk, anonymous, and voluntary.

1st Question: List and rank three traits (1-3) that you believe define a leader (1 being the most important, and 3 being the least important of the three).

2nd Question: From the list below, rank five traits that you believe define a leader (1 being the most important, and 5 being the least important of the five).

List of traits:
- Charismatic
- Articulate
- Humorous
- Witty
- Bilingual
- Confident
- Honest
- Ethical
- Tall
- Fluent English speaker
- Adaptable
- Stable
- Sociable
- Goal-oriented
- Conscientious
- Well-groomed
- Diplomatic
- Demanding

3rd Question: From the list below, rank five traits that you believe least define a leader (5 being the least important of the five).

List of traits:
- Charismatic
- Articulate
- Humorous
- Witty
- Bilingual
- Confident
- Honest
- Ethical
- Tall
- Fluent English speaker
- Adaptable
- Stable
- Sociable
- Goal-oriented
- Conscientious
- Well-groomed
- Diplomatic
- Demanding

4th Question: Please read the two scenarios below and answer the following question.

Scenario 1: Bob, captain of the Science Olympiad team at Liberty High School, is very passionate about his team winning their state competition this year, which is taking place in just three days. By winning this competition, they can receive a full-ride tuition scholarship to a local university, and if they lose, half the team will most likely attend a poor community college, if any school at all. Their coach gives the team a list of questions to do for practice, but Bob's teammates do not think they will have enough time to complete the questions, correct their mistakes, and then be ready for their upcoming competition. Bob's teammates become extremely frustrated and urge Bob, as a leader, to take action. Thus, Bob decides to go into his coach's office, steal the answer key, and distribute the answers to his teammates. He listened to his teammates, took action, and made a difference for his team, which ultimately resulted in them winning their state competition for the first time in ten years. The great news is that everyone on a team received a scholarship, and they are all looking forward to earning their Bachelors degree now.

Scenario 2: Peter, captain of the Science Olympiad team at Dunkin High School, is very passionate about his team winning their state competition this year, which is taking place in just three days. By winning this competition, they can receive a full-ride tuition scholarship to a local university, and if they lose, half the team will most likely attend a poor community college, if any school at all. Their coach gives the team a list of questions to do for practice, but Peter's team does not think they will have enough time to practice thoroughly, and Peter and his team lost at the state competition, resulting in no scholarships, even though it did not result in them winning the state competition.

Please state who you feel is the more effective leader, Bob or Peter, and briefly explain why:

5th Question: Indicate your gender:

Male
Female

6th Question: What is your ethnicity?

Hispanic or Latino
Not Hispanic or Latino
7th Question: What is your race? Mark all that apply.
White
Black or African American
Asian
American Indian or Alaska Native
Native Hawaiian or Other Pacific Islander

8th Question: Are your parents divorced or separated?
Yes
No

9th Question: What is the highest level of education your mother received?
No High School diploma
High School Diploma
Some college (No degree)
Associate's Degree
Bachelor's Degree
Master's Degree
Doctorate Degree

10th Question: What is the highest level of education your father received?
No High School diploma
High School Diploma
Some college (No degree)
Associate's Degree
Bachelor's Degree
Master's Degree
Doctorate Degree

11th Question: What grade are you currently enrolled in?
9th Grade
10th Grade
11th Grade
12th Grade

Leadership Traits Categorized into Groups:

Group 1
Common Sense
Practical
Simple

Group 2
Accountable
Conscientious
Dedication
Dependable
Disciplined
Efficient

Group 3
Able to Compromise
Adaptable
Available
Collaborative

Group 4
Cooperative
Flexible
Open-mindedness
Public Relations
Self-less
Unifying
Versatile

Group 5
Altruistic
Approachable
Compassionate
Courteous
Empathetic
Good-for-all
Humble
Loyal
Patient
Respectful
Sacrifice
Sincere
Trustworthy

Group 6
Ambitious
Assertive
Decisive
Demanding
Driven
Goal-oriented
Initiative

Group 7
Articulate
Charismatic
Effective Communicator
Eloquent
Listens well
Negotiable
Passionate
Persuasive
Strong Presence

Group 8
Diplomatic
Impartial

Group 9
Analytical
Educated
Intelligent

Group 10
Ethical
Fair
Honest
Strong Integrity

Group 11
Amiable
Enthusiastic
Optimistic
Sociable

Group 12
Composed
Level-headed
Stable

Group 13
Confident
Courageous
Individualistic

Group 14 (Other)
Bilingual
Candor
Competent
Fluent English Speaker
Good-Looking
Humorous
Ingenuity
Irresponsible
Obedient
Reserved
Strong
Stubborn
Tall
Transparent
Well-groomed
Witty
REFERENCES


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