

## Monitoring the Pipeline: STEM Education in Rural U.S.

Nancy Marksbury, Assistant Professor, Keuka College

*Abstract:* Higher education institutions are charged with creating one million more STEM professionals over the next decade, a 34% increase in undergraduate STEM degrees annually (PCAST 2012). Examining why college STEM courses manifest high attrition rates, interdependencies emerge that begin in early childhood education. Those of us in higher education recognize the need to transcend the boundaries separating our institutions, and this study describes one effort to lend support for elementary districts on the verge of immerse technology. Through the lens of a case study, teacher professional learning for STEM education in a rural setting in the northeast U.S. is explored. The study reports on a small-scale professional learning initiative for elementary school teachers, measuring current levels of confidence in science instruction and technology integration. A snapshot of technology infusion and confidence in teaching STEM among elementary teachers in the pre-implementation phase of their districts' 1:1 device deployments is reported. While recognizing barriers to persistence and engagement in STEM at the primary, secondary and higher educational levels of the system, it often takes a concerted effort to tackle big problems. Authentic learning experiences, innovative curricula, and increased teacher efficacy are required to engage students in finding suitable solutions for today's problems and tomorrow's challenges.

STEM (Science, Technology, Engineering and Mathematics) education receives the lion's share of attention, funding, and research in the United States. The nation is falling behind in its ability to remain competitive within a globalized society. For liberal arts education, the "T" in STEM is often interpreted as computing. The U.S. Congress passed the STEM Education Act of 2015<sup>1</sup>, making technology a STEM discipline. Not only does computational infusion help students better comprehend STEM principles and perform better in other STEM subjects, it gives students the tools and thought processes to apply to STEM concepts for solving complex problems, or as Jeannette Wing suggests, it develops "computational thinking" (2006). Using the example of simple data collection, recording and analysis using Google spreadsheets in elementary school can prime students' later understanding of scientific observations and deductions. Regardless of the specific field of expertise one pursues, a basic understanding of computers and computational thinking is essential (National Academies 2010, Yadav et al. 2014).

Despite the predicted employment prospects for the nation's STEM workforce, there are more far-reaching reasons for attention to declining enrollments in STEM subjects and fluency in these capabilities. "Poor student achievement in science translates into dimly low adult scientific understanding" (Epstein and Miller 2011, 4). And, in the current age of misinformation, disinformation, and fake news, the ability to think critically and act accordingly impact the status of our democracy, planet and lives.

This paper provides an introduction to the multiple factors behind why college students tend to be STEM-adverse and an overview of other factors contributing to low enrollment in STEM majors. Next, attention is turned upstream to review barriers to engagement and persistence in STEM content before students arrive at college. Through the lens of a case study, these and other precipitating conditions are examined within a small group of elementary educators.

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<sup>1</sup> "H.R.1020 - 114th Congress (2015-2016): STEM Education Act of 2015." <https://www.congress.gov/bill/114th-congress/house-bill/1020>.

## Introduction

Post-secondary first- and second- year students in STEM most often struggle due to:

- Gaps in prerequisite knowledge and skills necessary to succeed in STEM gateway courses.
- Insufficient time beyond scheduled class hours where students can pre-learn and re-learn required course content.
- Lack of support to improve student success and persistence in the form of people and systems.
- Lack of support for faculty to lead pedagogical reform.

To understand the systemic mechanisms that affect students' interest in persisting through difficult course content, we must look in both directions of the educational pipeline—from students in higher education to those currently in primary and secondary education—so that we can identify the barriers to STEM engagement and persistence and marshal resources available to improve our educational persistence and attainment.

### Looking Downstream: Barriers to STEM Engagement and Persistence In College

Addressing interest and persistence in STEM majors requires a multifaceted approach that considers the academic, emotional, cultural, and resource needs (NAS 2011; Goonewardene et al. 2016) of the individual student. Pyzdrowski et al. (2013) identified three broad areas that define student indicators of success in difficult topics, like math and science: Prior experience, instruction, and attitude and effort. These factors are exacerbated by socio-economic status—students from the wealthiest families outscore those from the poorest by almost 400 points on SAT scores (Zumbrun 2014). College enrollments across the nation rose during the recession, but nearly all growth was among low-income students (College Board 2017). A demographic shift in undergraduate enrollments and Pell status has resulted, highlighting the need for student academic support structures described below.

#### Underrepresented Minorities

Johnson (2011) found the average percentage of African-Americans enrolled is 2.4% in total. When compared to the average of STEM majors of 7.8%, we can deduce that African-American STEM major enrollment is very low. With fewer numbers of minority students enrolling in STEM majors, it is heartening that community colleges are seen as educational pipelines for Hispanic and Native American students into STEM majors.

The important role played by community colleges as an educational pipeline for URM is gaining recognition. Approximately 40% of students graduating with a bachelor's degree in STEM attended a community college (Chen & Weko, 2009). Furthermore, a large portion of community college students are not college ready, represent historically underserved populations, and are first-generation college goers (Juszkiewicz, 2014). We also know that there is a high attrition rate in STEM disciplines for these students and a relatively low degree completion record for community colleges overall (approximately 35% of community college students graduate with a two-year degree within six years, Juszkiewicz, 2015). It is both prudent and advantageous to include community colleges in our examination of learning and teaching strategies to support an increased number of students successful in STEM disciplines.

#### Characteristics of at-risk students entering a STEM major

In 2015, only 28% of high school graduates nationwide met or surpassed ACT benchmarks for college readiness across 4 subject areas, and only 16% of Hispanic and 13% of African- American students met or surpassed those benchmarks (ACT 2015). Scholars operationalize the concept of college readiness by placement scores, SAT benchmarks, or most difficult high school math course completed (Castleman,

Long, and Mabel 2014). Advocates of using multiple measures for gauging readiness suggest using a combination of metrics, specifically those that are an aggregation of high school math courses passed, a measure of their difficulty, and combined with scores for those courses. These have greater predictive validity for African-American and Hispanic students' success in aspiring to STEM majors (Ngo and Kwon 2015). Another measure of college readiness uses mean math placement scores, ranging from college-prepared (87.14) to college-unprepared (52.88), and students' mean math SAT scores (568 and 538 respectively) for courses completed (Hesser and Gregory 2016). Conversely, prepared students qualifying for NSF-based grants (STEM-S) were reported to start college with a mean high school GPA of 3.65 and combined SAT scores of 1,175 (Kalevitch et al. 2015). It appears that in general, high school curricula do not necessarily prepare entering college freshmen for more rigorous coursework, and greater deficiencies appear in mathematics.

While researchers document connections between mathematics and interest in STEM courses, students also identify that math self-efficacy, exposure to math and science in high school, and math achievement in high school are predictors of math readiness in college (Wang 2013). Between 2003-2009, 69% of associate degree-seeking students entering STEM majors dropped out with mathematics as the primary hurdle (NCES 2013), and 93% of Americans report negative feelings when learning math (Pyzdrowski et al. 2013). Math aptitude is an indicator of STEM orientation, can be measured in multiple ways, and its deficiencies mitigated by addressing student confidence and teaching practices. The latter involves social interaction in the math classroom, study skill intervention, and goal setting (Cho and Heron 2015). "Mathematics is central to our technology, society and culture, yet goes unnoticed most of the time" (Bengtsson 2014, 48).

Affectively, underprepared students demonstrate less deliberateness, lowered persistence, and dispositional issues (Melzer and Grant 2016). While measures of adjustment, motivation, and self-perception are strong predictors of college success, particularly for underrepresented minorities (Ngo and Kwon 2015), personal resilience is as important a factor in persistence to graduation as is academic grit. Additionally, URM often face financial barriers to STEM coursework and degree completion (Castleman, Long, and Mabel 2014). Choosing a STEM field of study is significantly and positively influenced by student ethnicity (particularly for Asian and Caucasian students) and socioeconomic status (Wang 2013). Once enrolled, URM are likely to have less frequent interactions with faculty than white students (Hurtado et al. 2011). Female persistence in STEM lags overall, and this situation is exacerbated by coursework rigor that can produce loneliness and social isolation (Koçak 2008). Learning can be negatively impacted by the awareness that others hold expectations that one's gender or ethnicity makes them less capable (Rydell, Rydell, and Boucher 2010).

#### How institutions mitigate those risk factors

Institutional interventions tend to fall into three broad categories: community building, cognitive development, and developing vocational interests and science identities (Lane 2016). Most appear to combine aspects of the first two: community building and cognitive development. For example, Hunter College increased their graduation rate among STEM majors by 75% with a multi-semester enrichment program, early alerts, and keeping their program structurally nimble (Salmun and Buonaiuto 2016). Multiple component programs that include various bridge and enrichment components, support structures that are both in- and out-of-class, smaller classes, peer mentoring, and financial support effectively increase retention and degree attainment for all STEM majors (Booth et al. 2014; D'Souza et al. 2015; Goonewardene et al. 2016; Lane 2016). Raines (2012) reports a retention rate of 91% for a pre-college summer bridge program addressing math deficiencies for a cohort that was predominantly female. Institutions implementing learning supports, both in-course (Gross et al. 2015; Ní Fhloinn et al. 2014) and out-of-class drop-in centers or informal learning labs (Denson et al. 2015; MacGillivray and Croft 2011;

Solomon, Croft, and Lawson 2010), helped students persist, achieve, and grow their confidence, camaraderie with peers, and application of math and science.

The third category of institutional intervention, i.e., developing vocational interests and science identities, is identified as playing a major role in STEM persistence. The University of Florida reported pre-research activities before and throughout students' first semester reduced barriers to involvement in faculty-led activities and increased student confidence (Schneider et al. 2016). Spelman College credits success for assisting African-American females with STEM career attainment by offering undergraduate research opportunities and other components, such as small class size, faculty encouragement and promotion, and academic supports (Perna et al. 2009). STEM majors themselves point to undergraduate research and interaction with faculty as activities that help them develop independence, confidence, and their science identity (Agarwal 2011; Gross et al. 2015; Hurtado et al. 2011; Thiry, Laursen, and Hunter 2011). These opportunities, accompanied with reliable, timely and tailored advising, are supports that STEM scientists point to as influential in their own development as a scientist (Ovink and Veazey 2011; Venville et al. 2013).

#### *Faculty responses to mitigate risk factors for persistence and attainment*

Knowledge and application of evidence-based pedagogies can improve achievement by helping students process new information more deeply and transfer new understanding to novel situations (Mulnix, Vandegrift, and Chaudhury 2016; Nadelson 2016). For example, traditional lecturing may disadvantage students with diverse learning preferences (Bernold, Spurlin, and Anson 2007) and activate only superficial student learning (Allendoerfer et al. 2014). Dialogic interaction (Tofel-Grehl and Callahan 2016), higher-order feedback and questioning (Hall and Miro 2016), strengthening individual motivation (Nguyen and Goodin 2016), and drawing connections between content and real-world experiences can generate active engagement and enthusiasm (Perna et al. 2009). Atypical assignments in a STEM classroom can increase conceptual knowledge and improve quiz scores (Fredricks et al. 2016; Sterling et al. 2016), while interactive, collaborative group problem-solving activities help students prepare to transition from novice to expert (Hajra and Das 2015; Richey and Nokes-Malach 2015). Support for technology integration and course redesign for infusing local and global issues with STEM content (Kazempour and Amirshokoohi 2013), combining lecture and lab content (Thompson et al. 2016), and embedded instructional support in the course (Hesser and Gregory 2016), helped underprepared students think strategically and metacognitively, and become more confident (Collins-Webb, Jeffery, and Sweeder 2016).

One's prior experience, quality of instruction and individual attitude and effort are qualities common students who persist in rigorous coursework. College readiness is predicted by one's scores of courses in math and science and the rigor of that coursework. Socioeconomic factors, like poverty, and the lack of access to quality educational experiences and STEM-related role models may restrict underrepresented minorities to greater degree. Novel teaching strategies and institutional interventions, while costly, can mitigate the lack of persistence in the college years. Yet, students need to be engaged in STEM long before the rigor of coursework threatens.

#### **Looking Upstream: Barriers to STEM Engagement and Persistence Before College**

Math and science achievement in the middle and high school years is a good predictor for students choosing a 4-year college degree (Martinez and Guzman 2013) and the pursuit of a STEM degree (Crisp, Nora, and Taggart 2009; Riegle-Crumb et al. 2012). Yet, previous findings on obstacles to engagement with and persistence in STEM courses point to a gender gap and differences that surface in middle school and high school, long before students get to college.

Since problems of engagement and persistence are noted before students attend college, upstream effects on students in primary and secondary educational levels have received research attention. At the

elementary level, standardized mathematics test scores appear to show few gender differences (Keiper et al. 2009). But there is some evidence that by the middle school years, females become less interested and less confident about math and science (Bacharach, Baumeister, and Furr 2003). More recent statistics suggest that twelfth-grade student scores for 2013 NAEP mathematics are unchanged from 2009 (NCES 2013). Nationwide percentages of students scoring at or above the level of proficiency declined for both males' and females' achievement in science. Further inspection of 2009 NAEP performance indicators reveals that females are scoring significantly below males in 12<sup>th</sup> grade assessments in math and science in the areas of biology, chemistry, physics, and advanced mathematics subjects (Cunningham, Hoyer, and Sparks 2015). These indicators suggest that interest and confidence in math and science instruction declines for females and that overall, math achievement is remaining constant rather than improving.

Engaging students in science and math involves intrinsic and extrinsic components around students' previous pedagogical experiences, their understanding of future occupational pathways, and their parents' dispositions, to name just a few (Venville et al. 2013). Adults in STEM careers report being strongly impacted by pedagogical demonstrations and projects in their early school years (Venville et al. 2013). Students in college are often able to pinpoint a specific teacher or experience that led to their adoption of the mind-set that STEM subjects "are not for me." Instructors need to nurture childrens' natural identity as scientists interested in and curious about our natural world, and yet they may be inadequately prepared themselves to align science, engineering, math and computational thinking topics with their students' development capabilities (Doabler and Fien 2013).

Beilock et al. (2010) identified a causal connection between math anxiety of first- and second-grade female instructors and their female students' math achievement. Younger students tend to internalize the enthusiasm and interest in math expressed by their teachers (Jackson and Leffingwell 1999), and this has severe consequences for all learners, particularly for girls who identify with their female teachers.

Much work has been done to advance student performance in learning about science. Sadler et al. (2013) correlated students' science concepts they hold, misperceptions about those concepts, and teacher subject-matter knowledge with science learning. Results suggest that student achievement can be improved when teacher science competency is strong. When a teacher can isolate students' erroneous thinking—particularly when students are asked to predict and observe—students will think longer and harder about the underlying issues (Sadler et al. 2013). A meta-analysis of challenges science teachers face suggest that teachers were found to have "unsophisticated understandings" or "widely inadequate conceptions" of science (Davis, Petish, and Smithey 2006, 614). On its own, technology integration is a challenge; challenges to incorporate STEM content and computing concepts in primary classrooms can make teaching a daunting task.

### The Influence of Socioeconomic Factors

Rural districts across the US encounter challenges that are often overlooked when evaluating national data. Many students lack Internet access at home and may not have access to computing devices due to poverty and/or the lack of broadband access. ISP vendors have yet to extend utility lines to all locations, especially where rural population density is sparse and scattered. Schools in some rural areas are separated by distance and socioeconomics. Technology is often under-utilized. Some educators are improperly trained and for example do not allow their students to touch Smart Board installations. In other instances, educators grapple with low-level software issues like document sharing in Google apps. Neighboring colleges and universities can play an integral role in expanding the capability of educators, particularly when professional development efforts had simply not caught up with the pace of technological adoption.

**A Case Study: Reaching Out in Our Neighborhood**

To better prepare students for college and the 21st century workforce, several rural school districts in central western New York State were approved for obtaining a matching grant<sup>2</sup> enabling a 1:1 device deployment for all students in K-12 in qualifying districts. Yet, the funding was limited to hardware and infrastructure purchases only, providing no support for pedagogical instruction for those teachers charged with managing and infusing devices and technology into their curricula. Interested in forging connections with area school districts, a private college sought to provide professional development workshops utilizing their technology integration professionals. Recognizing the challenges presented to neighboring school districts, experiencing the multiple states of preparedness with which students arrive to college, and wishing to participate in a broader effort to enhance student interest and persistence in STEM choices, we proposed to district leadership a plan for partnering with them to help prepare district teachers for the device deployment.

School districts in small rural communities are often challenged by low tax bases, and as in this case study, high poverty levels among families. Poor nutrition, inadequate health care, intellectual disabilities, and undiagnosed conditions are typical demands to address (Emerson 2004) and impact student attention, reasoning, learning and memory. As such, free- and reduced-priced lunch eligibility is often an indicator of need within school districts. Table 1 displays enrollment rates for economically disadvantaged and free and reduced-price lunches of those districts targeted for professional development.

**Table 1. Student enrollment by school with poverty indicators 2014-15<sup>3</sup>**

	K	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	6 <sup>th</sup>	Economically Disadvantaged (% of total K-6)	Free Lunch Eligible (% of student body)	Reduced Price Lunch Eligible (% of student body)
District 1	69	48	51	33	52	43	56	236 (66%)	354 (49%)	78 (11%)
District 2	57	50	51	43	45	66	54	173 (47%)	135 (36%)	30 (8%)
District 3	128	96	88	98	81	91	114	332* (57%)	291* (50%)	38* (7%)
District 4	22	27	22	38	30	25	38	132 (33%)	162 (41%)	51 (13%)
<b>Total</b>	<b>276</b>	<b>221</b>	<b>212</b>	<b>212</b>	<b>208</b>	<b>225</b>	<b>262</b>	<b>873 (54%)</b>	<b>942 (58%)</b>	<b>197 (12%)</b>

\*K-5 only

**Effective Professional Development**

According to Goodnough, Pelech, and Stordy (2014) providing effective technology-integration of STEM-related professional development to in-service teachers requires relevance, opportunities for collaboration and sharing, and the opportunity to develop practical applications for content relevant to their curricular outcomes. Their qualitative study differentiates between the idea of professional development as something *done to* elementary teachers as opposed to professional learning that helps individuals to “construct their knowledge and develop their skills” (pp. 69-70). A similar dichotomy exists in the focus of in-service teacher instruction: Is the instructional aim to enhance teaching by using technology, or is it aimed at using technology to support subject matter understandings? Longitudinal results by Kersaint,

<sup>2</sup> Smart Schools Bond Act: Educational Management : P-12 : NYSED.” 2017. Accessed July 15. [http://www.p12.nysed.gov/mgtserv/smart\\_schools/](http://www.p12.nysed.gov/mgtserv/smart_schools/).

<sup>3</sup> “New York State Department of Education Enrollment.” 2016. <https://data.nysed.gov/enrollment.php>.

Ritzhaupt, and Liu (2014) suggest that learning about technology integration needs a content-specific focus to help in-service teachers engage students and enhance subject matter understandings. Attitudes toward technology for children's learning, confidence, and the promise of support in implementation also directly affect technology use in the classroom (Blackwell, Lauricella, and Wartella 2014).

Effective professional development that improves instruction features immersive opportunities for comparing pedagogical approaches, considering the range of students' abilities for a given subject, and lesson plan critique that is collaborative (Gerard et al. 2011). Their extensive literature review also summarized that the capacity of technology for improving student achievement depends more heavily on pedagogy, content knowledge and instructional goals than on the design of the technology itself, and it is also noted that when professional development programs included lengthier collaborations, data collection, and support for overcoming obstacles, student experiences were improved (Gerard et al. 2011). Features for professional development programs include sustainability, collective participation, clear goals, real-world problems with worked examples, modeled behavior, authentic and integrated activities, active learning, building on foundational knowledge, demonstration of new knowledge, and reflection on actions (Van den Bergh, Ros, and Beijaard 2014). While it has been difficult for researchers to clearly link professional development efforts and student achievement gains, increasing teachers' knowledge of and confidence in teaching, substantially impacting teachers' classroom practices helps them to support instruction and student achievement (Greenleaf et al. 2011).

While local agencies offered several choices for state-sponsored professional learning opportunities by specific application, delivery preference and by varying schedules, these professional development occasions afforded little long-lasting support. Some were single day events and tended to apply to teachers of all grades with questionable differentiation for ages. None of the available workshops provided teachers with a community-of-practice encouragement, sustained, individualized support, and small cross-district cohorts of teachers of the same grade level. Other offerings were structured to include a three-hour kick-off and six weekly webinars, and were not likely to sustain engagement among participants over time.

Particularly with the advent of a new school year that would feature 1:1 device deployment for all students, the goals of the professional development were designed to help prepare educators to meet the critical needs of providing students' with access to quality instruction. Specifically, a curriculum was designed to prepare teachers to help their students engage with and persist in STEM subjects, infuse computational thinking and awareness of STEM- and CT-related careers for students from kindergarten through 3<sup>rd</sup> grade.

Believing it was incumbent on those of us at the higher educational level to help other educators prepare for STEM and CT course pathways and expectations not yet required in New York state classrooms, we organized workshops for multi-district skill development and lesson planning. Hoping to attract 75 educators, we drew only 25. Without support for attendance, most teachers chose not to participate in the workshops despite their principals' and superintendents' encouragement. We persisted with our decreased enrollment, however, and the following sections describe the results of our data collection.

### **Methodology**

The goal of the study was to assess the current practices, prior knowledge and confidence in infusing technology into STEM instruction among a small group of rural K-3<sup>rd</sup> grade teachers who participated in a professional development activity in the summer, 2016. We aimed to help these teachers prepare for the upcoming 1:1 device deployments and to boost their confidence for, attitudes toward, knowledge of, and efficacy for infusing technology into STEM instruction. IRB approval was sought and granted for the study plan and instruments employed.

During the end of the prior school year, participants completed a survey that collected demographic and background information on their qualifications, classroom practices, and prior experience with infusing

technology. At the beginning of the workshop, participants completed a modified version of the UTAUT instrument (Venkatesh et al. 2003) to identify potential barriers to technology adoption. Participant confidence in STEM instruction (Nadelson et al. 2013) was assessed at the outset of the workshops as well. Twenty-five teachers from three districts participated in a full-day workshop that focused on integrating freely-available Internet resources for math, science and social studies instruction in the context of desktops and tablets. Teachers were segregated into the grade levels taught, and each group circulated through three units on technology infusion for math, science and social studies.

Survey responses were collected online and then downloaded and transferred into Excel. Frequencies were analyzed and categories of ratings were collapsed into larger categories or removed entirely when outlying responses made the results meaningless. SPSS v.22 was employed to conduct descriptive statistics and correlations.

### Participant Demographics

Of the 25 teachers, all but two taught either kindergarten or grades 1-3. Most described their subject specialty as general education. In terms of their experiences teaching, 24% (6) of the teachers were relatively new with less than five years' professional experience, another 24% had six to ten years' experience, 16% (4) with up to fifteen years' experience, and the remaining 36% (8) were veterans of between 16 and 26 years' experience. All but two participants were female.

### Results

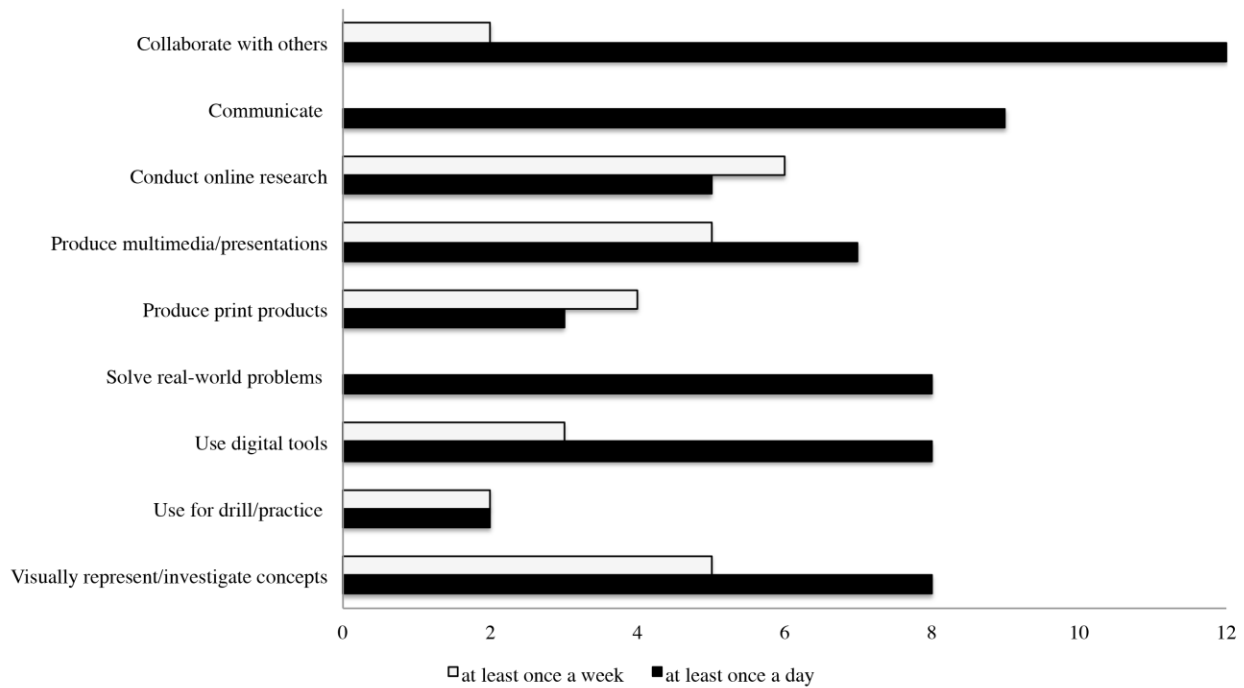
Three instruments were used to assess teachers' prior knowledge and experience with technology infusion, self-described barriers to technology adoption and confidence in STEM instruction. All surveys were administered online and data were analyzed in SPSS. Analyses are limited to frequencies and correlations, given the small number of participants and the lack of comparative data.

Background information on teacher qualifications, attributes, and classroom practices were administered first and prior to the workshop. Internal consistency was assessed by computing the reliability score ( $\alpha = .89$ ), indicating a reliable measure.

We were interested in knowing the extent to which technology was used prior to the 1:1 device deployment. Using the broad categories and indicator definitions of student standards promoted by ISTE ("ISTE | Standards For Students" 2016), we asked participants to indicate the frequency with which students used technology in activities that reflect those standards. Answer choices ranged from daily, weekly, monthly to quarterly, with optional boxes for rarely/never and not applicable (n/a). Ratings of rarely/never and n/a were quite prevalent; ratings of monthly and quarterly were outliers. To simplify the graphic visualization, scales for monthly, quarterly, rarely and n/a were omitted, leaving only those activities on a daily or weekly basis. Figure 1 displays the frequency with which teachers reported students using technology to engage in that activity.



**Figure 1. Frequency of technology-enabled classroom activities**

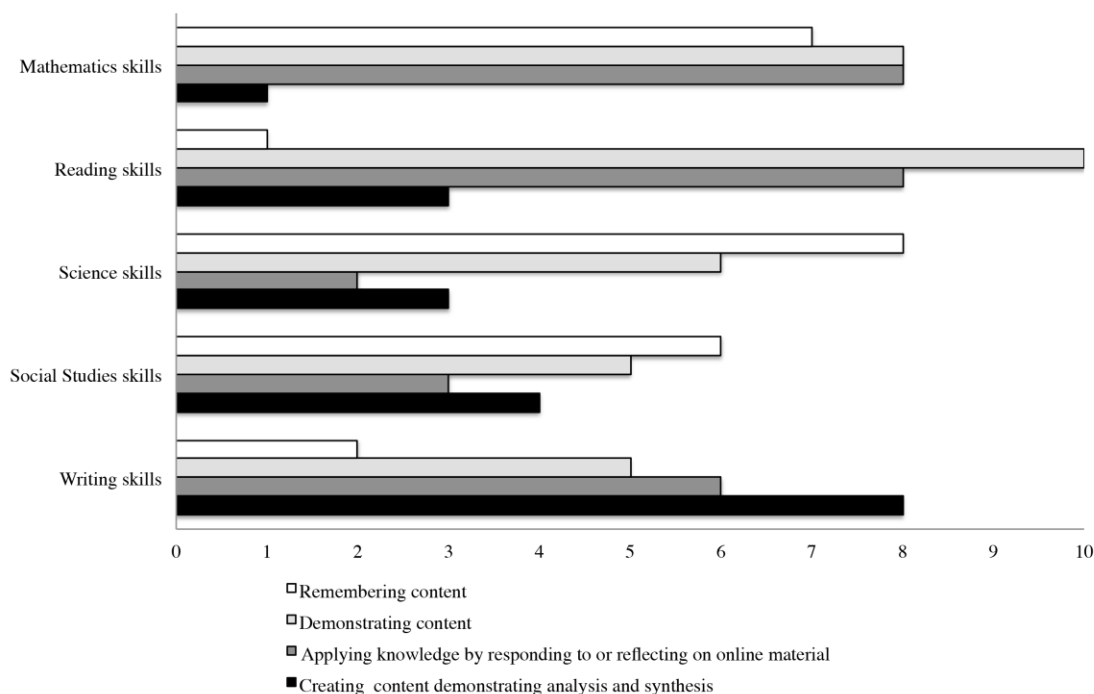


Collaborating with others, namely with students’ peers (within or between classrooms) was the greatest daily activity teachers reported. Twelve teachers reported they employed this activity daily, while only a third of the teachers reported encouraging their students to communicate with others (e.g., community members, experts, etc.) via email, video conferencing or other means. Low frequencies for communicating with others and conducting online research can probably be explained by the age and reading level of students in these grades. However, only a third of participants reported using digital tools (like cameras, probes, toys), producing printed products, and using technological resources for drill and practice are noted. As these activities seem like low-hanging fruit and are easily implemented, this may be explained by the lack of enough devices in the pre-deployment classrooms. Most concerning is that only eight teachers reported using technology daily to solve real world problems, involving the kinds of situations students are likely to encounter in their daily lives. However, this too may be attributable to a lack of access.

Correlations between these dependent variables and the independent variables of grade level, subject, professional experience and time at the current institutions were conducted and one was significant. Producing multimedia and presentations was moderately correlated with grade level taught  $r(23) = .45, p < .05$ .

Participants then were asked to identify the role technology plays in skill building for specific subjects. We wanted to know if and how teachers connected technology-related activities as enhancements for developing student proficiencies in subjects like reading, writing, math, science, and social studies. Specifically, we asked “In your classes, what role does technology play in building the following skills or proficiencies in your students?” Answer choices were presented in a matrix featuring the cognitive domains of remembering, demonstrating, applying and creating. figure 2 depicts teacher attribution of technology and subject skill development.

**Figure 2. Teacher attribution of technology to skill development**

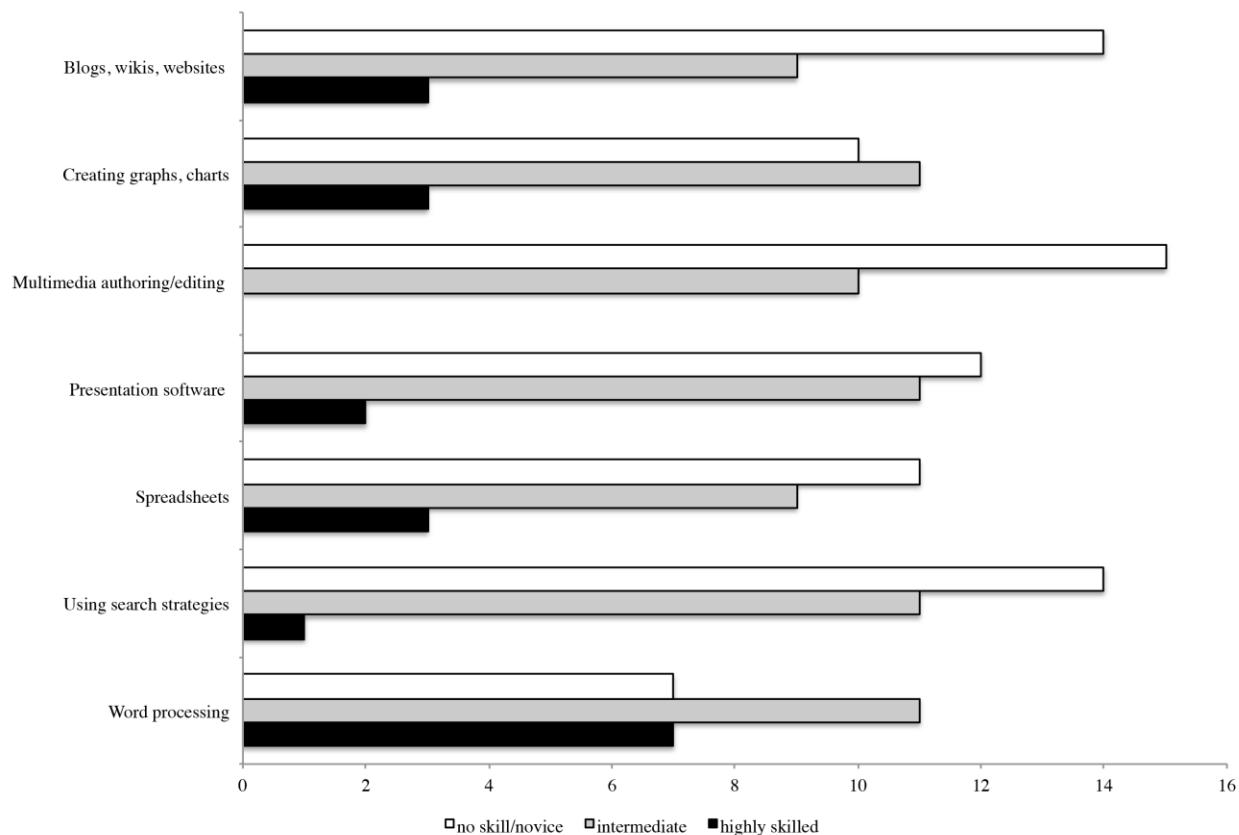


Higher frequencies centered on utilizing technology for math and reading skills. In other words, teachers viewed technology as generally useful for remembering, demonstrating, and apply mathematical concepts, but not so much for creating. For developing reading skills, technology was seen as helpful for demonstrating concepts and applying tasks, but less so for creating. Teachers’ ratings of the role of technology and developing reading skills was moderately correlated with grade level taught  $r(23) = .59, p < .01$ .

Science and social studies skills were similarly rated in that participants viewed technology as useful in helping students remember content, demonstrate concepts, but much less so for applying that knowledge and for creating in science and social studies. Technology’s role in helping developing science and social studies skills were moderately correlated with grade level taught: Science  $r(23) = .58, p < .01$ ; social studies  $r(23) = .45, p < .01$ . The development of science skills through using technology was also moderately correlated with the subject teacher’s taught  $r(23) = .43, p < .03$ . For developing writing skills in their students, technology was more likely to be used for applying and creating in student work.

Because teachers will likely be more successful when teaching what they themselves are comfortable with and enthusiastic about, we asked teachers to rate their own technical skill levels. Answer choices included no skill, novice, intermediate, and highly skilled. Answers for no skill were combined with novice because of the fine line of demarcation between the two ratings. Figure 3 illustrates those self-ratings.

**Figure 3. Teacher ratings of technical self-competency**



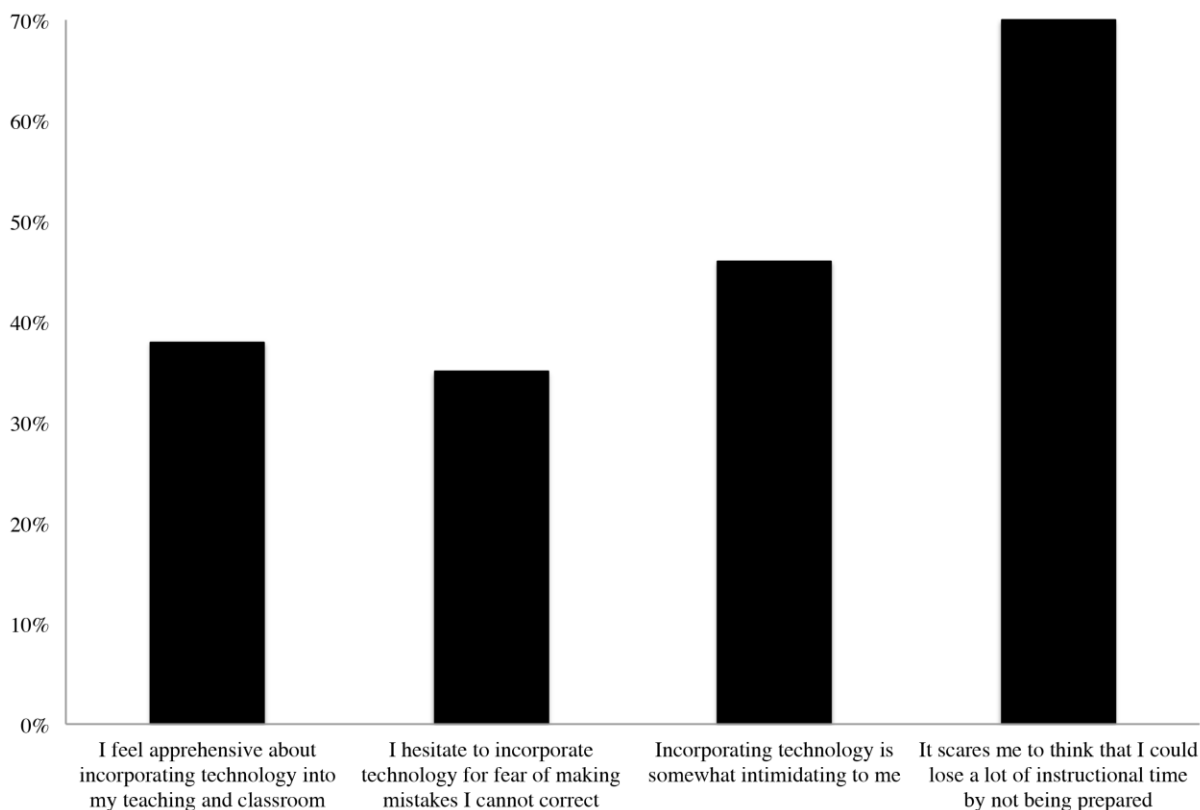
Excepting word processing, more than half of teachers rated themselves as having novice skills or no skills in all other competency categories. Only 7 teachers rated themselves as being highly skilled in word processing and 4 for spreadsheets. Intermediate ratings were assigned by a little over a third for most categories. Three teachers rated themselves as highly skilled in self-authoring tools (blogs, wikis, websites), creating charts, and presentation software. Only 1 teacher was highly skilled in utilizing search strategies, and no teachers were highly skilled in multimedia authoring.

There were several moderately negative correlations of skill categories and the number of years in their current district for rating their competency with these media. Blogs, wikis, websites  $r(23) = -.48, p < .02$ ; multimedia authoring  $r(23) = -.44, p < .03$ ; and utilizing search strategies  $r(23) = -.51, p < .02$  were significantly correlated. Utilizing search strategies was also moderately negatively correlated with the total number of career years teaching  $r(23) = -.51, p < .02$ .

Secondarily and at the workshop meeting, the UTAUT instrument (Venkatesh et al. 2003) was used to evaluate barriers to technology adoption. Recognizing that technology skill adoption is largely reliant on users' intent to use a particular device or technology, Venkatesh et al. posit three direct determinants of intention to use (performance expectancy, effort expectancy, and social influence) plus two direct determinants of usage behavior (intention and facilitating conditions). Further, the theory accommodates for moderating influences of experience, voluntariness (willingness to engage), gender and age. Each item included a 6-point scale ranging from strongly disagree to strongly agree.

Internal reliability was assessed ( $\alpha = .76$ ) as adequate. While most responses were overwhelmingly positive, ranging from somewhat agree to strongly agree, we focus only on those ratings of somewhat disagree to strongly disagree. Figure 4. illustrates negative frequencies which were concentrated in only four prompts.

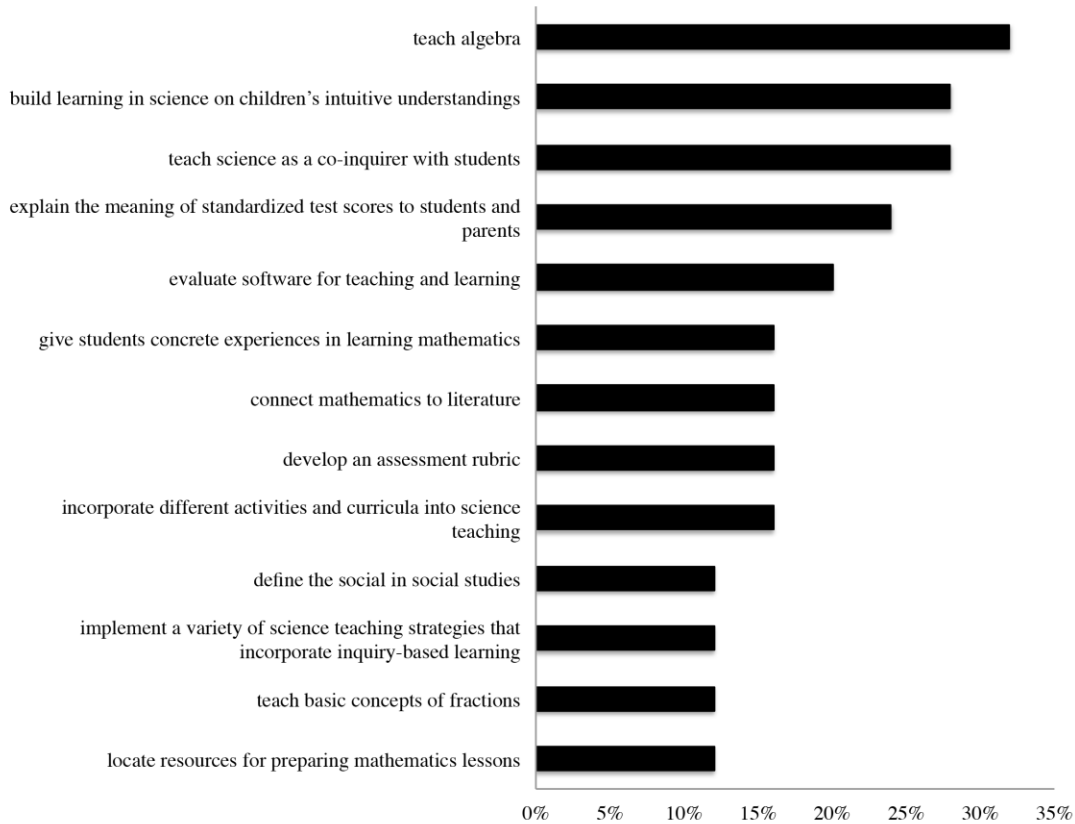
**Figure 4. Anxiety as a barrier to technology infusion**



Participants in our study were clearly concerned about losing instructional time, feeling intimidated and apprehensive about incorporating technology. Nearly half felt apprehensive about integrating technology and 70% of participants expressed anxiety about being fully prepared.

Lastly, elementary teacher confidence in STEM was assessed (adapted from Woolfolk Hoy 2000). Each item included a 6-point scale ranging from strongly disagree to strongly agree. Internal reliability was assessed ( $\alpha = .95$ ) and found to be highly reliable. Aggregated ratings were divided between items with mostly highly positive frequencies and those with mostly negative frequencies. Respondents unanimously indicated strong agreement with general teaching competencies like being able to manage their classroom, construct student-centered activities and utilize cooperative learning approaches to learning in their classroom. While there was less overall agreement with other general teaching aptitudes, like facilitating class discussions, evaluating students' work, and integrating language arts in their teaching, the majority of participants responded mostly positively to these prompts. Of those response frequencies rating items in the negative range (strongly disagree to disagree), it is interesting to note the items are all STEM-based. Figure 5 illustrates frequencies rated more negatively.

**Figure 5. Negative indicators for confidence in teaching stem subjects**



A third of participants rated the ability to teach algebra negatively, while a quarter of participants responded negatively to two science-related items: Building on childrens’ intuitive understandings in science and teaching science as a co-inquirer. Other items related to math instruction and interpretation, stand out as deficiencies among our participants.

### Discussion

The goals of our professional learning workshop were to assess teachers’ current practices and self-ratings about technology, and their confidence in integrating technology into STEM instruction just prior to starting a new school year with 1:1 device deployments across three rural school districts.

Based on the results obtained from three attitudinal surveys, at least three determinants influenced K-3 teachers in our three-district rural sample: Tenure, technology and teacher learning. Significant correlations with the independent variables of years of professional experience and time at current district surfaced. Also significant were correlations between the ways within which individuals reported interacting with technology and subjects in which teachers lacked confidence for teaching. Each category is explained.

#### Tenure

## Forum on Public Policy

Our participants were naturally divided into two tenure-related independent variables: The total number of years of professional experience teaching and the amount of time teaching at the current district. Twelve teachers (48%) were relatively new teachers with no more than 10 years' experience; 13 (52%) had taught anywhere between 11 and 25 years. Half of the participating teachers had been in their current position 5 years or less; and the remaining 13 claimed a wide range of 6 to 25 years in their current position. Self-ratings of skill and time at their current district were negatively correlated with self-authoring tools like blogs and wikis, multimedia creation and editing and internet search strategies. Internet search strategies were also negatively correlated for years of professional experience.

Half of our participants had been teaching for 10 years or less, and this presupposes their educational training occurred since 2000 when most students would be exposed to some of the basic competencies in their undergraduate careers. Combined ratings of no skill and novice frequencies across categories were greater than the sum of all intermediate and highly skilled ratings, except for word processing. While primary school teachers need not necessarily demonstrate technical expertise, the demand for teachers to begin exposing students to technical skills towards competency is not lessening. Teachers need the confidence, support and opportunity to adopt technical fluencies.

### Technology

Despite the half-new, half-veteran tenure among participants, 70% of respondents rated a concern for losing instructional time for the lack of appropriate preparation. This question was posed in context to a series of other items on technology, and it follows that it is the preparation of instruction and technical fluency these teachers are concerned. Suggestions of anxiety, feeling intimidated and apprehension were noted as drawbacks to integrating technology in their classrooms. Statements of standard teaching proficiencies and classroom management confidence were generally unanimous. When viewed in the context of participants' results on the confidence in STEM instrument, it is clear these teachers are far more comfortable in general teaching practices than they are with incorporating math- and science-related content in their teaching. Even at the elementary levels of K-3, nearly a third of participating teachers were skeptical of their ability to teach algebraic concepts, build on their students' intuitive understandings and teach as a co-inquirer with their learners.

Teachers' low attributions of technology for student skill-building in the subjects of math, science and social studies may signal additional reluctance in teaching STEM content. Students need engaging pedagogical experiences to advance their own curiosity about the natural world and how things work. However, this deficiency may be related to the pre-implementation of 1:1 devices; teachers may not have had access to enough technology to teach in technology-infused ways.

### Teacher Learning

Teacher reticence with technology is but one precipitating factor in what is described as a vicious cycle of students ill-prepared for and resistant to STEM. There are multiple agencies funded by the state to assist with the professional development needs of educators in public school systems. Teachers are incentivized to participate during the summer months, and sometimes throughout the school year. Yet those opportunities rarely embody the results of research findings for teaching professionals: extended collaborative opportunities with others, reflection, assistance with knowledge construction and skill development.

Without engaging pedagogical experiences throughout the K-12 years, awareness of the variety of STEM careers and multi-ethnic role models, how can students make claim to a vision of what may be possible? Especially for small, rural districts that struggle to teach students from lower socioeconomic backgrounds, and educators who lack support for professional development, post-secondary institutions find themselves struggling to attract better students who are prepared and/or provide programming to bridge educational

deficits for the students they attract. Unfortunate for many, this cycle occurs at a time when higher education itself is under assault financially. Depending upon students' readiness, cognitive development is required for content acquisition, study skills, and adjusting to changing expectations of college courses. Success in rigorous coursework is advanced by the encouragement and social supports that happen in and outside of class. Evidence-based pedagogies employed in the classroom help educators address the wide variety of learning preferences and preparation level of all students. While it may be too soon to gauge the success of Common Core State Standards—designed and instituted to increase college preparedness (Burks et al. 2015) around 2013, these are times all stakeholders in the educational pipeline must work together to provide the very best for all our students.

### Limitations

Despite our best efforts to recruit teachers for participation, only 25 responded to our call for participation. Not only does this make for a small participant pool, there are also only 3 districts from which participation was drawn. Additionally, the correlations generated are unexplained occurrences, despite some of the logical suggestions offered for interpretation. Other limitations include the distance of two months between the first survey and the final data collection; however, the results represented here reflect a snapshot of technology infusion and confidence in teaching STEM among elementary teachers in the pre-implementation phase of their districts' device deployments.

### Conclusion

With the overall number of high school graduates in the United States expected to plateau over the next several years while simultaneously becoming more diverse, colleges and universities must do more to increase student enrollment in STEM degrees, particularly underrepresented minorities and ensure their success. Substantially lowering STEM fields' high rate of attrition for females, URM, and all students, regardless of their major, is of paramount importance.

Improving the nature and quality of the undergraduate experience in STEM requires academic support throughout students' academic careers, beginning in early childhood. Students as well as teachers require sustained and consistent support in using technology to understand how things work and how problems get solved. These goals cannot be solved with single devices or sporadic exposure. For students to become interested in the larger contexts of a democratic society, culturally- and socially-relevant real work problems need to be integrated into their learning. Teachers need support to re-envisioning relevant curricula. Support in the form of professional learning opportunities are likely to be welcome, but we need to remove the barriers that make access difficult.

To ensure today's generation, and subsequent generations do not fall behind their parents' standard of living, to promote critical thinking, scientific literacy, and access to occupations that help humankind maintain a healthy planet, federal support for our children's education, their educators, and the institutions in which they are taught requires innovation and determination. Only by monitoring what is happening both downstream and upstream in our educational pipeline can we attend to and remedy the challenges.

## References

- ACT. 2015. "The condition of college & career readiness." *ACT*.  
<http://www.act.org/content/act/en/research/condition-of-college-and-career-readiness-report-2015.html>.
- Agarwal, V. 2011. "Undergraduate research: A transformative pedagogy for teaching in the natural sciences." *International Journal of Science in Society* 2 (2): 181–88.
- Allendoerfer, C., D. Wilson, M.J. Kim, and E. Burpee. 2014. "Mapping beliefs about teaching to patterns of instruction within science, technology, engineering, and mathematics." *Teaching in Higher Education* 19 (7): 758–71.
- Bacharach, V. R., A. A. Baumeister, and R. M. Furr. 2003. "Racial and gender science achievement gaps in secondary education." *The Journal of Genetic Psychology* 164 (1): 115–26.  
doi:10.1080/00221320309597507.
- Beilock, S. L., E. A. Gunderson, G. Ramirez, and S. C. Levine. 2010. "Female teachers' math anxiety affects girls' math achievement." *Proceedings of the National Academy of Sciences* 107 (5): 1860–63. doi:10.1073/pnas.0910967107.
- Bengtsson, A. 2014. "Liberal arts inspired mathematics: A report on how to bring cultural and humanistic aspects of mathematics to the classroom as effective teaching and learning tools." *Journal of Humanistic Mathematics* 4 (1): 16–71. doi:10.5642/jhummath.201401.04.
- Bernold, L. E., J. E. Spurlin, and C. M. Anson. 2007. "Understanding our students: A longitudinal study of success and failure in engineering with implications for increased retention." *Journal of Engineering Education* 96 (3): 263–74.
- Blackwell, C. K., A. R. Lauricella, and E. Wartella. 2014. "Factors influencing digital technology use in early childhood education." *Computers & Education* 77 (August): 82–90.  
doi:10.1016/j.compedu.2014.04.013.
- Booth, E. A., M. M. Capraro, R. M. Capraro, N. Chaudhuri, J. Dyer, and M. P. Marchbanks III. 2014. "Innovative developmental education programs: A Texas model." *Journal of Developmental Education* 38 (1): 2–18.
- Burks, B.A., T. L. R. Beziat, S. Danley, K. Davis, H. Lowery and J. Lucas. 2015. "Adapting to change. Teacher perceptions of implementing the Common Core State Standards." *Education* 136, no. 2: 253-258.
- Castleman, B. L., B. T. Long, and Z. A. Mabel. 2014. "Financial barriers to STEM study in college: Causal effect estimates of need-based grants on the pursuit and completion of courses and degrees in STEM fields." Society for Research on Educational Effectiveness. <http://www.sreee.org>.
- Cho, M.H., and M. L. Heron. 2015. "Self-regulated learning: The role of motivation, emotion, and use of learning strategies in students' learning experiences in a self-paced online mathematics course." *Distance Education* 36 (1): 80–99. doi:10.1080/01587919.2015.1019963.
- College Board. 2017. "Undergraduate enrollment and percentage receiving Pell grants over time - Trends in higher education." The College Board. <https://trends.collegeboard.org/student-aid/figures-tables/undergraduate-enrollment-and-percentage-receiving-pell-grants-over-time>.
- Collins-Webb, A., K.A. Jeffery, and R. D. Sweeder. 2016. "Understanding the impact of a general chemistry course on students' transition to organic chemistry." *Journal of STEM Education: Innovations & Research* 17 (2): 26–33.
- Crisp, G., N. Amaury, and A. Taggart. 2009. "Student characteristics, pre-college, college, and environmental factors as predictors of majoring in and earning a STEM degree: An analysis of students attending a Hispanic serving institution." *American Educational Research Journal* 46 (4): 924–42. doi:10.3102/0002831209349460.
- Cunningham, B. C., K. Mulvaney Hoyer, and D. Sparks. 2015. Gender differences in science, technology, engineering, and mathematics (STEM) interest, credits earned, and NAEP performance in the 12th grade. National Center for Education Statistics. <https://eric.ed.gov/?id=ED554303>.



- Davis, E. A., D. Petish, and J. Smithey. 2006. "Challenges new science teachers face." *Review of Educational Research* 76 (4): 607–51. doi:10.3102/00346543076004607.
- Denson, C. D., C. Austin Stallworth, C. Hailey, and D. L. Householder. 2015. "Benefits of informal learning environments: A focused examination of STEM-based program environments." *Journal of STEM Education: Innovations & Research* 16 (1): 11–15.
- Doabler, C. T., and H. Fien. 2013. "Explicit mathematics instruction: What teachers can do for teaching students with mathematics difficulties." *Intervention in School and Clinic* 48 (5): 276–85. doi:10.1177/1053451212473151.
- D'Souza, M. J., W. K. Kroen, C. B. Stephens, and R. J. Kashmar. 2015. "Strategies and initiatives that revitalized Wesley College STEM programs." *Journal of College Teaching & Learning* 12 (3): 915.
- Emerson, E. 2004. "Poverty and children with intellectual disabilities in the world's richer countries." *Journal of Intellectual & Developmental Disability* 29 (4): 319–38. doi:10.1080/13668250400014491.
- Epstein, D. and R. T. Miller. 2011. "Slow off the mark. Elementary school teachers and the crisis in science, technology, engineering, and math education." Science Progress. Center for American Progress. <http://files.eric.ed.gov/fulltext/ED536070.pdf>
- Fredricks, S. M., J. Tierney, M. Bodek, and M. A. Fredricks. 2016. "Developing student presentation skills in an introductory-level chemistry course with audio technology." *Journal of College Science Teaching* 45 (4): 46–46.
- Gerard, L. F., K. Varma, S. B. Corliss, and M. C. Linn. 2011. "Professional development for technology-enhanced inquiry science." *Review of Educational Research* 81 (3): 408–48. doi:10.3102/0034654311415121.
- Goodnough, K., S. Pelech, and M. Stordy. 2014. "Effective professional development in STEM education: The perceptions of primary/elementary teachers." *Teacher Education and Practice* 27 (2/3): 402–22.
- Goonewardene, A. U., C. A. Offutt, J. Whitling, and D. Woodhouse. 2016. "An interdisciplinary approach to success for underrepresented students in STEM." *Journal of College Science Teaching* 45 (4): 59–67.
- Greenleaf, C. L., C. Litman, T. L. Hanson, R. Rosen, C. K. Boscardin, J. Herman, S. A. Schneider, S. Madden, and B. Jones. 2011. "Integrating literacy and science in biology: Teaching and learning impacts of reading apprenticeship professional development." *American Educational Research Journal* 48 (3): 647–717. doi:10.3102/0002831210384839.
- Gross, D., E. Iverson, G. Willett, and C. Manduca. 2015. "Broadening access to science with support for the whole student in a residential liberal arts college environment." *Journal of College Science Teaching* 44 (4): 99–107.
- Hajra, S. G., and U. Das. 2015. "Undergraduate students' perceptions of collaborative learning in a differential equations mathematics course." *College Student Journal* 49 (4): 610–18.
- Hall, A., and D. Miro. 2016. "A study of student engagement in project-based learning across multiple approaches to STEM education programs." *School Science & Mathematics* 116 (6): 310–19.
- Hesser, T. L., and J. L. Gregory. 2016. "Instructional support sessions in chemistry: Alternative to remediation." *Journal of Developmental Education* 39 (3): 22–28.
- Hurtado, S., M. K. Eagan, M. C. Tran, C. B. Newman, M. J. Chang, and P. Velasco. 2011. "'We do science here': Underrepresented Students' interactions with faculty in different college contexts." *Journal of Social Issues* 67 (3): 553–79. doi:10.1111/j.1540-4560.2011.01714.x.
- ISTE. 2016. "Standards for Students" <http://www.iste.org/standards/standards/for-students#startstandards>.
- Jackson, C. D., and R. J. Leffingwell. 1999. "The role of instructors in creating math anxiety in students from kindergarten through college." *The Mathematics Teacher* 92 (7): 583–86.
- Johnson, D. R. 2011. "Women of color in science, technology, engineering, and mathematics (STEM)." *New Directions for Institutional Research* 2011 (152): 75–85. doi:10.1002/ir.410.
- Kalevitch, M., C. Maurer, P. Badger, G. Holdan, and A. Sirinterlikci. 2015. "Building a community of scholars: One university's story of students engaged in learning science, mathematics, and

- engineering through a NSF S-STEM grant - Part II.” *Journal of STEM Education: Innovations & Research* 16 (2): 40–45.
- Kazempour, M. and A. Amirshokoohi. 2013. “Reforming an undergraduate environmental science course for nonscience majors.” *Journal of College Science Teaching* 43 (2): 54–59.
- Keiper, S., B. A. Sandene, H. R. Persky, and M. Kuang. 2009. “The nation’s report card: Arts 2008 -- music & visual arts. National assessment of educational progress at grade 8.” NCES 2009-488. National Center for Education Statistics.  
<https://nces.ed.gov/nationsreportcard/pdf/main2009/2010451.pdf>.
- Kersaint, G., A. D. Ritzhaupt, and F. Liu. 2014. “Technology to enhance mathematics and science instruction: Changes in teacher perceptions after participating in a yearlong professional development program.” *Journal of Computers in Mathematics and Science Teaching* 33 (1): 73–101.
- Koçak, R. 2008. “The effects of cooperative learning on psychological and social traits among undergraduate students.” *Social Behavior & Personality: An International Journal* 36 (6): 771–82. doi:10.2224/sbp.2008.36.6.771.
- Lane, T. B. 2016. “Beyond academic and social integration: Understanding the impact of a STEM enrichment program on the retention and degree attainment of underrepresented students.” *CBE-Life Sciences Education* 15 (3): ar39. doi:10.1187/cbe.16-01-0070.
- MacGillivray, H., and T. Croft. 2011. “Understanding evaluation of learning support in mathematics and statistics.” *International Journal of Mathematical Education in Science & Technology* 42 (2): 189–212. doi:10.1080/0020739X.2010.519801.
- Martinez, S. and S. Guzman. 2013. “Gender and racial/ethnic differences in self-reported levels of engagement in high school math and science courses.” *Hispanic Journal of Behavioral Sciences* 35 (3): 407–27. doi:10.1177/0739986313495495.
- Melzer, D. K., and R. M. Grant. 2016. “Investigating differences in personality traits and academic needs among prepared and underprepared first-year college students.” *Journal of College Student Development* 57 (1): 99–103. doi:10.1353/csd.2016.0004.
- Mulnix, A. B., E. V. H. Vandegrift, and S. Raj Chaudhury. 2016. “How important is achieving equity in undergraduate STEM education to you?” *Journal of College Science Teaching* 45 (4): 8–11.
- Nadelson, L. S. 2016. “The influence and outcomes of a STEM education research faculty community of practice.” *Journal of STEM Education: Innovations & Research* 17 (1): 44–51.
- Nadelson, L. S., J. Callahan, P. Pyke, A. Hay, M. Dance, and J. Pfiester. 2013. “Teacher STEM perception and preparation: Inquiry-based STEM professional development for elementary teachers.” *The Journal of Educational Research* 106 (2): 157–68. doi:10.1080/00220671.2012.667014.
- NAS. 2011. “Expanding underrepresented minority participation: America’s Science and technology talent at the crossroads.” The National Academies of Science, Engineering and Medicine.  
<http://nap.edu/12984>.
- National Academies, National Research Council, and National Academy of Sciences. 2010. “Report of a workshop on the scope and nature of computational thinking.” National Academies Press.
- NCES. 2013. “STEM attrition: College students’ paths into and out of STEM fields.”  
<http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2014001rev>.
- Ngo, F., and W. Kwon. 2015. “Using multiple measures to make math placement decisions: Implications for access and success in community colleges.” *Research in Higher Education* 56 (5): 442–70. doi:10.1007/s11162-014-9352-9.
- Ní Fhloinn, E., O. Fitzmaurice, C. Mac an Bhaird, and C. O’Sullivan. 2014. “Student perception of the impact of mathematics support in higher education.” *International Journal of Mathematical Education in Science & Technology* 45 (7): 953–67. doi:10.1080/0020739X.2014.892161.
- Nguyen, G.T. and J. B. Goodin. 2016. “Bringing students back to mathematics: Classroom knowledge and motivation.” *Journal of Humanistic Mathematics* 6 (2): 47–83. doi:10.5642/jhummath.201602.06.
- Ovink, S., and B. Veazey. 2011. “More than ‘getting us through.’ A case study in cultural capital enrichment of underrepresented minority undergraduates.” *Research in Higher Education* 52 (4): 370–94. doi:10.1007/s11162-010-9198-8.

- PCAST. 2012. *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Report to the President.* Executive Office of the President. <http://eric.ed.gov/?id=ED541511>.
- Perna, L., V. Lundy-Wagner, N. D. Drezner, M. Gasman, S. Yoon, E. Bose, and S. Gary. 2009. "The contribution of HBCUS to the preparation of African American women for STEM careers: A case study." *Research in Higher Education* 50 (1): 1–23. doi:10.1007/s11162-008-9110-y.
- Pyzdrowski, L. J., Y. Sun, R. Curtis, D. Miller, G. Winn, and R. A. M. Hensel. 2013. "Readiness and attitudes as indicators for success in college calculus." *International Journal of Science and Mathematics Education* 11 (3): 529–54. doi:10.1007/s10763-012-9352-1.
- Raines, J. M. 2012. "FirstSTEP: A preliminary review of the effects of a summer bridge program on pre-college STEM majors." *Journal of STEM Education: Innovations & Research* 13 (1): 22–29.
- Richey, J., and T. Nokes-Malach. 2015. "Comparing four instructional techniques for promoting robust knowledge." *Educational Psychology Review* 27 (1): 181–218. doi:10.1007/s10648-014-9268-0.
- Riegle-Crumb, C., B. King, E. Grodsky, and C. Muller. 2012. "The more things change, the more they stay the same? Examining gender equality in prior achievement and entry into STEM college majors over time." *American Educational Research Journal* 49 (6). doi:10.3102/0002831211435229.
- Rydell, R. J., M. T. Rydell, and K. L. Boucher. 2010. "The effect of negative performance stereotypes on learning." *Journal of Personality & Social Psychology* 99 (6): 883–86. doi:10.1037/a0021139.
- Sadler, P. M., G. Sonnert, H. P. Coyle, N. Cook-Smith, and J. L. Miller. 2013. "The influence of teachers' knowledge on student learning in middle school physical science classrooms." *American Educational Research Journal* 50 (5): 1020–49. doi:10.3102/0002831213477680.
- Salmun, H. and F. Buonaiuto. 2016. "The Catalyst Scholarship Program at Hunter College. A partnership among Earth science, physics, computer science and mathematics." *Journal of STEM Education: Innovations & Research* 17 (2): 42–50.
- Schneider, K. R., D. Bahr, S. Burkett, J. C. Lusth, S. Pressley, and N. VanBennekom. 2016. "Jump starting research: Preresearch STEM programs." *Journal of College Science Teaching* 45 (5): 13.
- Solomon, Y., T. Croft, and D. Lawson. 2010. "Safety in numbers: Mathematics support centres and their derivatives as social learning spaces." *Studies in Higher Education* 35 (4): 421–31. doi:10.1080/03075070903078712.
- Sterling, E., A. Bravo, A. Luz Porzecanski, R. L. Burks, J. Linder, T. Langen, D. Fernandez, D. Ruby, and N. Bynum. 2016. "Think before (and after) you speak: Practice and self-reflection bolster oral communication skills." *Journal of College Science Teaching* 45 (6): 87–99.
- Thiry, H., S. L. Laursen, and A. Hunter. 2011. "What experiences help students become scientists? A comparative study of research and other sources of personal and professional gains for STEM undergraduates." *Journal of Higher Education* 82 (4): 357–88.
- Thompson, M. M., L. Pastorino, S. Lee, and P. Lipton. 2016. "Reenvisioning the introductory science course as a cognitive apprenticeship." *Journal of College Science Teaching* 46 (1): 84–84.
- Tofel-Grehl, C., and C. M. Callahan. 2016. "STEM school discourse patterns." *Journal of STEM Education: Innovations & Research* 17 (2): 34–41.
- Van den Bergh, L., A. Ros, and D. Beijaard. 2014. "Improving teacher feedback during active learning: Effects of a professional development program." *American Educational Research Journal* 51 (4): 772–809. doi:10.3102/0002831214531322.
- Venkatesh, V., M. G. Morris, G. B. Davis, and F. D. Davis. 2003. "User acceptance of information technology: Toward a unified view." *MIS Quarterly* 27 (3): 425–78.
- Venville, G., L. Rennie, C. Hanbury, and N. Longnecker. 2013. "Scientists reflect on why they chose to study science." *Research in Science Education* 43 (6): 2207–33. doi:10.1007/s11165-013-9352-3.
- Wang, X. 2013. "Modeling entrance into STEM fields of study among students beginning at community colleges and four-year institutions." *Research in Higher Education* 54 (6): 664–92. doi:10.1007/s11162-013-9291-x.
- Wing, J. M. 2006. "Computational thinking." *Commun. ACM* 49 (3): 33–35. doi:10.1145/1118178.1118215.

- Woolfolk H. A. 2000. "Changes in teacher efficacy during the early years of teaching." In *Proceedings of American Educational Research Association*.
- Yadav, A., C. Mayfield, N. Zhou, S. Hambrusch, and J.T. Korb. 2014. "Computational thinking in elementary and secondary teacher education." *ACM Transactions on Computing Education*. 14 (1).
- Zumbrun, J. 2014. "SAT scores and income inequality: How wealthier kids rank higher." *Real Time Economics*. October 7. <https://blogs.wsj.com/economics/2014/10/07/sat-scores-and-income-inequality-how-wealthier-kids-rank-higher/>.