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Abstract

In this article the principle investigators of the various projects that comprise Aggie STEM at Texas A&M University discuss the impact and cross pollination of having graduate students from Turkey working and conducting their research as part of the multi-college Aggie STEM project. Turkish students have been engaged in instrumental roles since the inception of Aggie STEM and its growth as a tightly intertwined multi-national and ubiquitous STEM entity. The influence of Turkish students has spanned the entire gamut, from app development, which preceded the trend at the beginning of the new millennium, to innovative curricula and pedagogies that became enculturated into everyday life. Perhaps the greatest contribution offered by the scholars is that, as students, they engaged broadly in research, published prolifically and continue in these activities as they assumed the mantle of leadership as tenure track professors, administrators, policy makers, and program officers in the U.S. and throughout the world.

Introduction

Myriad challenges lurk for the four disciplines of mathematics, science, technology, and engineering. Some may argue that only one is really a discipline and the others combine and reorganize information from one to form the other disciplines, where varying other skills become more or less emphasized depending on which other subject one is interested in. For example, science can be viewed as the messier and more natural exemplification of the precise mathematical world. Science would then be described as making observations of messy real world events in the attempt to quantify, generalize, and eventually assign a mathematical model that accurately describes observations. The reality is that each field builds on, relies on, and inter-reacts with the others more or less given some set of conditions, expectations, and potential outcomes.

There are many challenges facing Science, Technology, Engineering, and Mathematics (STEM) education and its successful implementation, none of which is greater than the ill-informed and self-proclaimed STEM educator or STEM education specialist. When the National Science Foundation transformed the arrangement of the starting letters for mathematics, engineering, technology, and science into the ubiquitous STEM, it created a void. What we know from science is that nature abhors a void. While the void concept works, consider evolution and the work of Darwin – species' voids are filled, unfortunately not always as elegantly as the now extinct specie that vacated it. Perhaps the more prominent void filler was Homo Sapiens. Many species have gone extinct since our arrival on the scene with about seven new extinctions every 24 hours (Vidal, 2011).

We rushed into the ecological landscape and quickly put our thumbprint on all other species and ecosystems on the planet and since then humans have become quite comfortable rushing into voids even when that help is often misguided and premature. That void created by the new term STEM became the destination into which many sprinted. Some transferred from business, some from law, and some from various education disciplines. The influx of non-subject matter specialists was potentially damaging to the STEM education mission. There were no credentials required to proclaim one's expertise in STEM other than to add four simple letters arranged into a now meaningful and pronounceable acronym, "STEM," to one's business card.

Multiplying Success

The idea of filling voids with STEM generalists is as repugnant as the potential loss of the Humpback whale, the platypus, or the mudskipper. The response to filling voids with STEM generalists is to train diverse people in ways that allow them to be aware of, responsible to, and tolerant of curricular diversity where groups of individuals work collaboratively to address STEM needs. Each person pursuing a STEM degree beyond the baccalaureate does so with the hope of deepening and enriching his or her knowledge of that subject. If that person persists in higher education, eventually she or he becomes an expert in that particular STEM discipline and earns a terminal degree (i.e, Phd or EdD). It is that terminal degree that signifies that expertise.

How do the ideas of disciplines and voids account for changes in the educational landscape that are influenced by STEM? The answer can be as convoluted as the problem. First, does the problem really exist? Is there really a thing called STEM education? If there is such a thing as STEM, how can it be described so that everyone who sees it knows that it is STEM? How is STEM different from what has always been done? Finally, what are the anticipated outcomes of STEM done well? While the answer is trite – "train diverse people in ways that allow them to be aware of, responsible to, and tolerant of curricular diversity where groups of individuals work collaboratively to address STEM needs" – it is not simplistic in implementation. It requires new and expanding collaboration, diversity, and dedication to change, or we are constrained to doing what has always been done and reaping the same outcomes we have seen historically.

Collaboration

Using the ideas from broad contexts explored through multiple lenses can provide insights to problems that would otherwise go unexplored or seemingly unanswered. What we learn from the multiplicative identity property is that the number of problems multiplied by one person exploring the problem results in the exact same number of problems. But the nature of STEM work is that we need to be able to explore more problems effectively, so we need to think about another property of multiplication that can afford greater success. The commutative property is one that can be made analogous to developing partnerships to solve problems, that is, multiple people working on multiple problems resulting in the same exact same number of solutions regardless of where we start, either with the number of problems or the number of people. The importance here is that while we have a fixed approach, the product or the solutions are greater than the identity condition given the same sample set. For example, from the identity property we had eight problems, and at the end we still had eight problems (8×1) because one person cannot really address them adequately. At best, we might actually find eight solutions. However, from the commutative property we started with eight problems and now have two people, so the potential solutions increase to 16.

The Origin of Aggie STEM

The collaborations began when Semsettin Beser, a very bright and talented young man from Ankara, arrived to contribute to the STEM transformation. His interests moved the entire mathematics education program into the idea of technology mediated instruction and assessment. He developed a very adaptable and secure testing and analysis system as part of his work towards his Masters of Science degree. The foundational impact of this work was that it lived well beyond his time at A&M. Six doctoral students and three master's students used that system after he graduated. But most importantly, the data gathered through that system gave rise to the first awarded grant that led to the inception of Aggie STEM. The multiplicative property gave way to the Associative property with another student – a top student Tufan Adiguzel. He assured that we understood the power of handheld computing technology and its impact on mathematics learning. While he performed his work in Educational Psychology, his work was groundbreaking, showing that personal handheld devices were acceptable both to students and teachers for "just in time" data collection (Adiguzel, Capraro, & Willson, 2011). However, the versatility of his work was not fully understood until it was broadly applied across all STEM disciplines. The work of Aggie STEM branched out to include clicker technology, iPads, and Moodle as an online course delivery model. Aggie STEM now reaches more than 300 teachers per year across the United States thanks to his contributions and the acceptability of on-line learning.

Another contributor, unique in many ways, in this era was Hamza Anderoglu. His major was counseling with a broad interest in psycho-social influences on learning. Through his interests, we explored the impact of Project-based learning on students' attitudes and interests to learn STEM subjects. His influence in this area was not fully realized until nearly four years after his graduation, when Aggie STEM earned its first grant award to explore and understand how students' feelings about STEM PBL influenced their achievement and desire to pursue post secondary STEM education. His perspective on and concern for the individual provided a catalyst that moved the research team to explore new inquiry methods and the courage to explore the more affective side of STEM teaching and learning (e.g., Corlu, Capraro, & Capraro, 2014).

Aggie STEM Reaches Critical Mass

As Aggie STEM grew, its work attracted a student, Sencer Corlu, whose interests would prove transformational in a very translational way. The foresight of the Ottoman Empire to build a system that accelerated the sciences and mathematics through an interconnected and multidisciplinary approach showed that our STEM problem was deeply rooted in the human condition. The Ottoman Empire had designed schools of choice with different foci to achieve different purposes and to meet the needs of its ever-expanding society. The mechanical designs that originated from the Matrakcı era in the Ottoman Empire were a precursor to engineering as a discipline and an early-integrated subject into science and mathematics. Sencer made the very important connection to these early foundations of STEM education that were laid circa 1299 (e.g., Corlu, Burlbaw, Capraro, Corlu, & Han, 2010). His work, based on early translated works, also demonstrated how schools of choice gave rise to in-depth study and had the potential to achieve greater gains than those possible in comparable schools of that era. His groundwork established a foundation on which subsequent students have built what has become a productive line of inquiry, that is, examining how modern day charter schools, STEM schools, and other incarnations of schools of choice influence the educational landscape and pockets of phenomenal success.

The nexus of science with the other subjects in STEM has been lacking, but the next transformational contribution came from an unlikely source. The science perspective was and remains orthogonal to some mathematical ideas. The conflict in these perspectives stems from using different sources of primary information about similar constructs, dependence on research methods that are distinct by discipline, and core differences in paradigm that permeate the subject to manifest as a unique culture. Niyazi Erdogan joined Aggie STEM on a trial basis to see how his research interests would intersect those of the group and to determine the potential for deep catalyzing change. The challenge would be not just accommodating his perspectives but integrating them into the core essence of what Aggie STEM would someday grow to be. His research built on the historical contributions of those who came before but grew into a multifaceted approach laden with policy implications related to the creation of schools of choice focused around the STEM concept (Erdogan, Corlu, & Capraro, 2013). The contribution opened the door to the finding that designated STEM schools, while implementing a specific program or guidelines, were not uniformly better than any other public school. This was not to say that STEM schools did not have bright spots, but they were univocal and tended to be most beneficial for traditionally underserved populations. Therefore, these schools of choice were not necessarily "worth" the added monetary investment it required to become a designated STEM school and with regard to science achievement were not hitting their mark.

As Aggie STEM added foci and integrated content greater diversity new paradigms arose. As part of those paradigms new and innovative quantitative designs. This earlier work has grown in scope and perspective with iterations from Ayse Tugba Oner and Ali Bicer. Each expanded on the prior contributions of their predecessors to build a more comprehensive view of charter schools, STEM schools, and STEM charter schools relative to comparable groups (Bicer, Navruz, Capraro, & Capraro, 2014; Bicer, Navruz, Capraro, Capraro, Oner, & Boedeker, 2015; Navruz, Erdogan, Bicer, Capraro, & Capraro, 2014). The sociological aspects of their work provide contexts by which there is a deeper understanding of the characteristics of successful schools and for which student subgroups those schools best serve. Another unique aspect of their work is the marked change in the research paradigm toward more rigorous research designs that make use of large datasets and careful selection of comparison groups through propensity score matching (e.g., Capraro, Capraro, Morgan, Scheurich, Jones, Huggins, Corlu, & Younes, (2015, In Press; Oner, Navruz, Bicer, Peterson, Capraro, & Capraro, 2014). The legacy of the forward thinking research designs has brought new expertise to Aggie STEM and provides benchmarks for subsequent students to follow.

Contributions to Aggie STEM are complex. Several others have contributed to Aggie STEM's gradual transformation. From work that examines mathematics in light of science achievement (e.g., Cetin, Corlu, Capraro, & Capraro 2015), to Bilgin Navruz's practical application of higher order factor analysis (Navruz, Capraro, Capraro, & Bicer, 2015 in press). Alpaslan Sahin's work shed light on high school course taking and SAT scores effect on college major selection (Sahin, Erdogan, Morgan, Capraro, & Capraro, 2012) and chapter on inquiry in the STEM PBL book (Sahin, 2013).

The idea of legacy lives on at Aggie STEM. Sencer Corlu provided a legacy that subsequent PhD students will benefit from. He was the first PhD student director and modernized the curriculum and deliver. That was refined and expanded by Rayya Younes and the Aggie STEM camp for secondary students became a popular event. Niyazi Erdogan expanded the legacy of STEM Camp to attract students from around the world to learn STEM content in authentic project based lessons. Under Niyazi's leadership, the camp grew from a few students in 2003 to over 100 spread across two camps; Ayse Tugba Oner expanded it to three camps and more than 170 students exploring life as a future undergraduate while learning STEM content from university professors and graduate students. Their legacy in leadership, hard work and dedication provide employment to 15 other graduate and undergraduate students who work with the middle and high school students each year. This offers a lasting testament, that a group of focused individuals can come together to influence the lives of secondary students while providing organizational structure so future Aggie STEM graduate and undergraduate students, and faculty can apply their research in practical-applied settings.

Visiting Scholars Add Cultural Capital

Visiting scholars from some of the best Turkish universities have contributed to the development of Aggie STEM. Scholars like Drs. Ozcan Erkan, Nesrin Ozsoy, and doctoral students like Zeynep Gecu, and Sabhia Yeni represent perspectives from Sakarya University, Adnan Menderes University, and Middle East Technical University. Their contribution brought perspectives that added to the revised edition of Project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach, (Akgun, 2013) understanding of how elementary teachers are prepared in Turkey, and knowledge of using iPads to teach coding to preschool children. It is the ability of scholars who possess deep understandings of their content from various backgrounds and come together to build a program with longevity. The continued flow of ideas and opportunities provide a symbiotic environment for growth and idea expansion.

Biodiversity

Biodiversity, in a not so pure a science interpretation, is the greatest contribution of graduate students and visiting scholars. It is difficult to look at things from "outside the box" when one cannot physically get outside their own box without help. What is meant is that, with few exceptions, without those who challenge our ideas, we cannot even find the perimeter of our boxes. So in developing a chapter on Turkish education, two doctoral students provided insights into what is likely the most thorough and detailed treatise on the Turkish middle level education system (Özel, Yetkiner, Capraro, & Küpçü, 2009), with all its achievements and challenges, published in English. It is in this document that we framed many underlying ideas that have guided Aggie STEM and its development into a comprehensive research entity.

The biodiversity contributes to deep conversations among students from Africa, China, India, Italy, Japan, Lebanon, Mexico, Poland, South Korea, and United States. The magnification of regional diversity and resulting conversations can demonstrate how similar we are as a people. Problems faced in one region of the world are actually common across the world, and the solutions are applicable and plausible in multiple regions. We, as a one-world community, learn from and through the lens from which the solution was applied regardless of the region of the world from which it emanates.

The biodiversity is a double-edged sword in that the U.S. obtains the best deal while Turkey's potential gains can turn into the same invisible entitlements that weigh so heavily on U.S. society. The U.S. receives an infusion of new ideas, hard work, and indelible marks on those who are touched by visitors. Turkish students, now colleagues and scholars in their own right and visiting scholars who return to their home countries, take western experiences that have the potential to enrich their society and build new and very powerful knowledge structures. The benefit to the home country is that it receives new knowledge, leaders with broad experiences and new ideas coupled with the U.S. sense of research excellence, and better access to and experience with research organizations and journals. However, with knowledge comes power, and power can be distributed unevenly and wielded along a continuum that can end with negative implications. The problem with exporting so many former PhD students, now STEM professional educators, back to Turkey is that they have the potential to develop into a tightly knit group that fosters a sense of over-reliance on who they have become and not on what they have to offer. The benefit of a U.S. STEM doctorate can be overshadowed by the same potential pitfalls that plague the U.S.

Equity, Entitlement, and Legacy

The ideas of equity, entitlement, and legacy are paramount issues for STEM education researchers. Once one earns a PhD in mathematics education or any STEM related field, one is bestowed with the greatest of benefits and endowed with a mystique that can be greater than the sum of all the parts that helped forge that terminal education. Earning a degree in any STEM field receives the same level of prominence. However, this awesome power should not ever devolve into a program of systemic entitlement and legacy. It is the responsibility of the smallest person who might be blessed with great power and influence to use that power to confront entitlement and legacy, providing a consequence of equity that transcends socio-political structures, cultural and religious lines, and languages.

Entitlement is one of those things that we cannot often recognize when we possess it. It does not come on a card you can put in your wallet or purse and is not a piece of jewelry you can wear, or an article of clothing that can be computer selected for you. However, we can be doggedly protective of it and not even know we have it. We can wield it with laser like precision or like a nuclear weapon and create broad and irreparable devastation. Entitlement structures come in many forms - they can be the color of our skin, the language we speak, our gender, our religion or sect within our religion, the university we graduated from, or our field of education.
Perhaps the most damaging entitlement is entitlement based on invisible structures. Knowledge was intended to be the great equalizer that would transcend all superficial entitlement structures. However, we are still slaves to base instincts to differentiate, to seek out the miniscule uniqueness that exists within subgroups and then attach artificial distinctions on those that create a legacy that leads to privilege for one group and that leads to neglect, at best, and failure, at worst, for the other. The distinctions are either good or bad - to which one we subscribe depends on how we interpret the distinction's effect on our standing within a community. As more of the world seeks equity through education, discourse around traditional differences is lost. It is substituted for more insidious and vile forms of transparent entitlement and legacy. These can be so ingrained that those who may feel that they challenge the construction of these structures fail to recognize them or, even worse, provide the raw materials for their construction.

"Being" a STEM educator or STEM professional comes with lucrative capital. This truly intoxicating concoction of recognition for what one knows and intimidation for what others do not is potentially a very dangerous condition. Therefore, one must surround oneself with others who are immune to this concoction to ensure measures are in place to keep those privileges in check. While Aggie STEM and countless other organizations within top U.S. universities have benefitted from exemplary Turkish students attending our universities, the merit of what they have been taught both intentionally and inadvertently has yet to be written. The quality of their mettle is indisputable; the forging of them into professionals who will assume the mantel of leadership as department heads, deans, provosts, and directors at Tübitak, Turkey's main science-funding agency analogous to the National Science Foundation in the U.S., and in prominent positions in the Ministry of Education is what has yet to be determined.

Turkey struggles with important global issues, and its governmental organizations are not immune to the socio-political whims of the day. For example, Tübitak rejected a workshop grant on the grounds that evolution is a controversial subject. The workshop was to expose Turkish biology students to population genetics, game theory, and evolutionary modeling. It was reported in Science that the workshop would continue with private donors contributing the money (Bohannon, 2013, July 5). Will events like this be diminished as more U.S. trained PhDs assume leadership roles? How will research conducted in Turkey be reported and inform the world community? How will general research topics evolve as the PhD's influence and power increases? Rest assured the world is watching and judging the quality of the professionals forged at top U.S. institutions.

Conclusion

In STEM education the consumer must be careful, as in any environment one's behavior should be caveat emptor. However, differentiating among and between charlatans, snake oils salesmen, and empirically derived programs that yield positive results can be difficult at best. There are criteria by which to judge the merit of any intervention and paramount to that set is the depth of the research base that underlies it. Today, everyone claims his or her program is research "proven." The first indication of frailties of any program is the claim of "proof" without qualifiers. No program is without qualifiers that the purveyors can clearly speak about for whom the program works and how long it takes to get results. One should know for whom any program works. The answer to this question should not be everyone. In the word "everyone" is hidden "I do not know." For every program the consumer must know how limited language proficiency, gifted, at-risk, minority groups, and international students, as well as students in special education, perform when using it. No program is without costs, both monetary and personal. Some programs are exorbitantly priced while others are more modest. Personal costs are especially pricey. Personal costs are the costs of reaching pedagogical proficiency for teachers, learning for students, and understanding for parents. Commonly, a careful customer would ask how long does it take for teachers to learn to use a specific program, and the response that should raise concern is, “teachers can take this program and run with it immediately.” The truth in this statement is that the teachers are likely to run from the program. It is important for the customer to understand how long it takes for teachers to be trained to use a specific program, how the fidelity of implementation is being monitored, and how long will it take for it to raise student outcomes that matter. Research indicates that teachers need at least 90 hours of professional development to successfully implement any new program, no matter how “teacher proof” anyone claims the program to be. It takes time for students to respond and parents to understand that their child will have new or expanded expectations. Follow-up and careful guidance are needed to ensure that teachers are implementing the program as designed and not in combination with many other components cherry picked from across discarded programs.

The reality is that the research base for most STEM programs is paper-thin at best, with mediocre sampling techniques. Often, reports of research are written based on convenience sampling, the lowest bar of research rigor (e.g., Shadish, Cook, & Campbell, 2002). The obtained results lack robustness, and effect size estimates are tenuous. It is more important to ask to see the research article that was published about the program and avoid making decisions based on glossy brochures, textbooks, manuals, or other sources that are not peer reviewed. The former Turkish students, now STEM content and pedagogical experts, are well-positioned to explore these issues, investigate claims, and to deepen our knowledge of what works, for whom, and under what circumstances.

The students from Turkey enriched the educational experiences in the U.S. by their presence, and they continue to contribute to the program through a multifaceted and complex but sometimes highly nuanced way. What they contribute is the sharing of educational ideas and deep reflection on what happens in the U.S. K-12 program. While our system is undergoing dramatic and sometimes detrimental change, Turkey is experiencing almost parallel situations. These student ambassadors reflect on their experiences, use knowledge of how their national education program is enacted, and draw parallels to trends and changes in the U.S. In the book Die Empty: Unleash Your Best Work Every Day, Todd Henry espouses a philosophy that the most valuable land in the world is the cemetery because it is where all the unrealized hopes, dreams, and good intentions are buried. It contains all the greatest dreams that were never enacted, the apologies never given, and the regrets never redressed. It is the repository of friendships lost and the greatest discoveries forgone that Turkish Scholars must avoid.

At some time, all scholars come to the conclusion that they have come to a place in life where they understand their time on this planet is all too short and that what little effort they have left and whatever time they have - - MUST be spent in ways that allow them to “DIE EMPTY.” If you do not fully understand what is meant here, consider reading the book. The professoriate should gravitate toward more liberal ideas and more liberal interpretations. This group should play a role in abolishing practices, whether readily apparent or inadvertently hidden, that provide for entitlements and legacy. Not that the road is easy or that there is not a great deal of stress and distress. It can be very lonely. The core of this belief system is that STEM education in the U. S. produces highly qualified teachers and researchers who are ready to assume the mantel of leadership in schools and universities. Perhaps some still need mentorship, but professors should love their students and colleagues and believe they embody the best there is to offer. We are a community of informed people with skills and talents that cannot be matched by any single country regardless of nationally comparative or internationally administered tests that might indicate differently. We cannot succumb to political rhetoric that says our teachers are the problem or that universities are inadequate. Politics and politicians need controversy and sometimes we (educators and others) inadvertently provide the platform. We must remember that our particular STEM field has given us so very much. The entitlement of being a STEM educator is truly an intoxicating and potentially dangerous one, so it is important to put checks in place to measure one’s own privileges to ensure one is staying in check and that one is serving the greater community, whether that community is across the street or around the world.

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