East Tennessee State University's STEM+C Proposal as it Compares to Other National Science Foundation Funded Programs

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Abstract

East Tennessee State University has submitted a funding request to the National Science Foundation for a STEM+C program in the Tri-Cities region, titled "Integrating Computing into the Traditional Curriculum in Mathematics". To gauge the potential success of this proposal, we have compared ETSU's proposal to other NSF-funded programs, drawing particular comparisons to programs in Colorado, Massachusetts, Virginia, and Washington, that share many similarities with ETSU's proposal. It is our opinion that such a program implemented in Tennessee would serve to raise test scores, increase STEM competencies, and better prepare students to enter a modern workforce increasingly reliant on computer software.

Introduction

Written by Joshua Leonard.

Science and technology increasingly impact our daily lives, however a national initiative aimed towards addressing this increase has not been proportional to the rising prevalence of science and technology in our society. This is not to say that there has been no national initiative, but simply that the initiative has not been sufficient as of yet. This paper hopes to provide a critical analysis of a STEM+C proposal put forth by ETSU (titled “Integrating Computing into the Traditional Curriculum in Mathematics”) to the National Science Foundation, particularly by comparing and contrasting it with extant STEM+C programs that have received funding from the NSF.

What is STEM+C?

Written by Joshua Leonard.

"STEM" stands for "Science, Technology, Engineering, and Mathematics," and sees its genesis during debates over education and immigration to "address the perceived lack of qualified candidates in high-tech jobs" [7]. This is, certainly, an issue we can observe today: future jobs lie in STEM fields, increasingly so, and the demand for individuals to fill these positions will necessarily increase. Indeed, PCAST, the President's Council of Advisors on Science and Technology, estimated that, over the next decade, the demand for STEM graduates will outstrip the number of STEM graduates produced by over one million [8].

Compounding this issue, however, is the rise of computing. As science and technology progresses, so too does our reliance on computers, and thus it is important for students to possess a fluency with computational software. Once more, a national initiative addressing computational fluencies in the classroom has went largely unaddressed until very recently. Thus, we are now observing the rise of STEM+C in our classrooms, with the aim of integrating computing into STEM curriculums. Per the National Science Foundation, "The STEM + Computing Partnerships (STEM+C) program seeks to advance a 21st century conceptualization of education in science, technology, engineering and mathematics (STEM) that includes computing, both as a STEM discipline in its own right consistent with the STEM Education Act of 2015 . . . and as a discipline integral to the practice of all other STEM disciplines" [9], with PCAST going so far as to call computer science the "third pillar of scientific practice" [9]. Indeed, the National Research Council lends additional support to this, highlighting the importance of computer competencies in the K-12 curriculum, concluding that such competencies are crucial for "succeeding in a technological society, increasing interest in the information technology professions, maintaining and enhancing U.S.

economic competitiveness, supporting inquiry in other disciplines, and enabling personal empowerment [9].

Unfortunately, because a concerted, national initiative towards STEM+C is such a (relatively) recent phenomenon, the NRC found there to be a lack of research which could guide the creation of such a curriculum (particularly for lower grades), let alone the professional development required to train the teachers. Such a program (one hoping to address and implement a STEM+C curriculum), an evidence base must be constructed for “new and effective pedagogy and pedagogical environments that will make the integration of computational thinking in other STEM disciplines, and computer science itself, increasingly more relevant through contextually relevant problem solving, applications, and activities” [9]. This is largely meaningless, however, if students are turned off by STEM, thus the curriculum must be sufficiently integrated such that students encounter a wide array of applications for the materials taught, and in culmination, a STEM+C curriculum must be responsible for preparing undergraduate students to encounter problems in STEM fields. In sum, “Such integration of computing with other STEM teaching and learning may well have profound effects on the way STEM is taught - reflecting the increasing role of computational approaches in learning across the STEM disciplines, and fostering more multidisciplinary and collaborative approaches for learning both in and out of school.”

National Initiatives

Written by Erica Fugate.

The need to improve and encourage the American educational system by placing emphasis on mathematics and science is being pushed by national initiatives. The demand for not only teachers, but also for capable math and science practitioners, in the workforce has caught the attention and been recognized by many powerful entities within the United States government. The Obama administration put forth a proposal entitled "Educate to Innovate", which placed emphasis on "striving for excellence in STEM education" [5]. "Educate to Innovate" was to be made up of both private and public investments totaling $250 million dollars. These crucial investments were going to be used in a multitude of ways, but a large portion was to be dedicated to preparing 10,000 new teachers entering the field of mathematics and science education, as well as 100,000 *current* teachers in these fields. This stands as one of the single largest attempts to reform the teacher education for readiness in STEM. A network of crucial partnerships was created in order to achieve the goals of the campaign: Intel's Science and Math Teachers Initiative; the Expansion of the National Math and Science Initiative's UTeach Program, a Commitment of Public University Presidents to Train 10,000 Math and Science Teachers Annually by 2015; the PBS Innovative Educators Challenge and Woodrow Wilson Teaching Fellowships in Math and Science all allied to "represent a combined commitment of more than $250 million in financial and in-kind support, adding to the more than $260 million in support announced in November at the launch of the "Educate to Innovate" campaign" [8]. In response to the efforts being taken to improve the teaching of STEM education, over 100 teachers have been awarded a Presidential award for excellence in STEM teaching and mentoring [5].

Besides President Obama and the above-mentioned, many other organizations have recognized the importance of STEM to the future and have started initiatives to act as catalysts for change. NASA has made a commitment to host a Summer of Innovation enrichment program. This program will have NASA scientist and engineers working closely with a group of teachers and students in applying and understanding the cutting-edge science opportunities opened up by STEM education [5]. In addition, the United States Department of Education has committed to awarding $100 million under the Teacher Quality Partnership program. This program seeks to improve the "recruitment, preparation, and licensure of teachers in high-need school districts", and will commit an additional $200 million dollars strictly dedicated to "pursuing effective performance-pay models and approaches to supporting and rewarding teachers in high-need schools" as supported by the American Recovery and Reinvestment Act [5].

The ultimate goal of these initiatives is to return the United States to the upper rungs of international STEM education within the next ten years, an area we have grossly fallen behind in. For the U.S. to remain competitive on the international stage, particularly in the job market, it must improve its mathematics and science education, and can do so through STEM initiatives.

Program Description

Written by Erika Hale.

The programs are broken into two tracks: (1) the Integration of Computing in STEM Education and (2) Computing Education Knowledge with Capacity Building. The Integration of Computing in STEM Education is labeled as "Track 1". This track works in a K-12 setting seeking proposals for teaching and learning that integrate computing into math and science using new strategies. Proposals to integrate science and math into computing would also be sought after in Track 1 [5], and partnerships with other STEM educators and schools, along with researchers at universities, is expected.

Computing Education Knowledge and Capacity Building is labeled as "Track 2". Keeping in mind that there is not a large amount of computing being done in the K-12 environment, Track 2 proposals should either "build an evidence base for effective modes of teaching, learning and supporting student success in computing within diverse populations" or "create evidence-based scalable models for teacher professional development and sustainable, ongoing teacher support" [5]. Track 2 proposals will be more theoretical than Track 1 proposals.

Both Track 1 and Track 2 consist of different "types". The three project types for Track 1 are (1) Exploratory Integration, (2) Design and Development, and (3) Field-Building Conferences and Workshops. Exploratory Integration is a project that will consist of specific research questions where the researcher could develop prototypes. The researcher will be obligated to report in detail their process, what was learned during the process, and the outcome. Funds of up to $1,250,000 is available for Exploratory Integration with a 3-year maximum duration period. Design and Development is a proposal that builds on already completed research. The intent is to "build upon work demonstrating promise for impact on student and teacher learning in classrooms" [5]. The purpose of Design and Development programs is to find improvements for STEM learning and then present it in such a way that this information will be shared with other researchers. Up to $2,500,000 is available for Design and Development with a 3-year maximum duration. Field-Building Conferences and Workshops is the third and final project type for Track 1, and this project type is for workshops, conferences, and other teaching resources to help people better understand how to integrate STEM disciplines into computing. The expectation of Field-Building Conferences and Workshops is for the proposed work to be outcome based. There are $250,000 in funds available for this project type with a 2-year maximum duration.

The two project types for Track 2 are (1) Research on Education and Broadening Participation Projects and (2) CS10K. The Research on Education and Broadening Participation Projects will focus on socio-cultural environments in both the rural and urban population. The focus of this research will be relevant to student learning in the scope of K-20 and concentrating on how well this population can use computing needed for higher education and future fields of study. Funds of up to $600,000 is available with a 3-year maximum duration. The CS 10K "aims to have rigorous, academic computing courses taught in 10,000 high schools by 10,000 well-prepared teachers" [5]. The proposals of CS10K must focus on efforts that will enable teachers to successfully offer the new courses; Exploring Computer Science (ECS) and/or Advanced Placement (AP) CS Principles. There are $1,000,000 in funds available for this project type with a 3-year maximum duration period.

There are a number of elements required in the proposals for both Track 1 and Track 2. Track 1 must entail multidisciplinary partnerships. "All projects are encouraged to consider broadening the project team, as is appropriate to the project, to include learning scientists, cognitive scientists, education researchers, discipline-specific teachers and faculty, school personnel and district leadership, educational, developmental, and social psychologists, social scientists, education technologists, out-of-school learning practitioners and researchers, informal educators, education media and technology developers, and representatives from business, industry, and school districts to inform career direction "[5]. Other elements of Track 1 include research, intervention types, teacher preparation and professional development, and project evaluation. The project evaluation must be completed by an external evaluator who is also outside the proposing institution. The proposal evaluation is expected to "describe the expertise of the external reviewer, explain how the expertise relates to the goals and objectives of the proposal" and also specify how the results of the evaluation will be used [5]. Collaborations is the first element of Track 2. The proposing team must be made up of people with expertise in both educational research and relevant to the project at hand. The team's expertise must also include learning sciences, cognitive science, developmental and social psychology, and/or the social sciences. The second element of Track 2 is attention to diversity. Demographics play important role in Track 2 projects and all projects must focus on a very diverse and multicultural group of people. "Data gathered in all proposals must be disaggregated by gender and ethnicity." The final elements of Track 2 include research, teacher preparation, and evaluation. The evaluation for Track 2 projects must have an intervention, formative and summative evaluation, must be performed by an independent evaluator and data collected must be disaggregated by gender, ethnicity, socioeconomic status, and disability unless precluded by state or local laws.

ETSU's Proposal

Written by Erika Hale.

ETSU is the lead partner in introducing a proposal titled "Integrating Computing into the Traditional Curriculum in Mathematics" (ICTCM). The supporting partners are six schools within four surrounding school districts. This proposal will be a Track 1, Exploratory Integration project, and the goal of this project is to integrate computer languages (specifically Python, R, and MatLab) into six high school level courses. The classrooms without existing computers will be furnished with Raspberry Pi devices in order to work application-based problems using these computer languages. A seven-person team of statisticians, educators, and computational mathematicians, in addition to five graduate students in Computational/Applied Mathematics or Statistics, will work under the guidance of an advisory board throughout the duration of this project.

"Twelve teachers will be directly engaged and trained each year, and around 600 students will benefit from, and be engaged in, the integrated courses during the last two years of the program (materials will be developed during year 1)." Because Computer Science or Computing classes are not generally available in our area this project will prepare first-generation college students in our high-school cohorts. "Students will thus be prepared for scientific computation in college and the workplace."

ETSU and the National Stage

Written by Erica Fugate.

Now that the need for STEM+C and how East Tennessee State University plans to address this need has been established, it is important to discuss other programs that have been funded by the National Science Foundation. All fifty states have the potential to apply for NSF funding for implementing STEM+C into the classroom, but not all of the states have received (or even tried to accomplish) this. There are many states that have received funding for multiple NSF grant proposals. Tennessee is one of the states that, to date, has not received funding for an NSF grant for implementing STEM+C into the classroom at any age. This lack of additional funding to attempt to better math and science education is reflected in national statistics; in 2013, Tennessee is ranked 45th out of 52 in 8th grade mathematics scores nationally that are at or above Proficient [4] (see Appendix C). The national average test score in mathematics was 284 and Tennessee's state average was 278 [4]. This may not seem significant, but considering that 87% of the states lies above Tennessee is math scores is significant enough to denote a problem. As for at or below Basic, Tennessee ranks 40th out of 52 in 8th grade mathematics scores nationally [4].

This leads to one important question: To what degree does ETSU's proposal, "Integrating Computing into the Traditional Curriculum in Mathematics", have a chance at receiving NSF funding? In order to answer this question, we shall need to compare ETSU's proposal to other programs having already received funding. In essence, the purpose of this comparison is to ultimately justify why ETSU's proposal should receive funding, based off of similarities and uniqueness to already-funded national programs. For the purpose of this paper, comparisons will be drawn based on the following five criteria: (1) Type of proposal, (2) targeted age range for STEM+C integration, (3) range of influence of the proposal,

(4) application of real-world scenarios using STEM+C, and (5) introduction of computer languages and modeling injected into the curriculum.

At present, there are a total of twenty-four states that have received NSF funding for the explicit purpose of integrating STEM+C into the curriculum (see Appendix B). For the above five criteria, when discussing criterion (1), it bears repeating that ETSU's proposal is a Track 1 Exploratory Integration proposal for $X. This is a significant criterion as fifteen of the twenty-four funded programs (62.5%) involve Exploratory Integration proposals. The range of awarded funding varies between $700,000 and $1.8 million, with one state, Arizona, as a significant outlier (see Appendix A). For criterion (2), ETSU's targeted age range targets students and teachers in grades six through twelve, both in-service and pre-service. Comparatively, fifteen of the twenty-four programs (62.5%) also target students and/or teachers falling in this age range (see Appendix A). For criterion (3), the range of influence of ETSU's proposal is rather small as compared to many other funded proposals, affecting only twelve teachers in six of the surrounding school districts, and comprising approximately 600 students. Additionally, around 60 teachers will be affected through summer programs. Only four of the funded programs (16.7%) have similar scopes (see Appendix A).

For criterion (4), the application of real-world scenarios and problems into the proposal is a central point of ETSU's proposal; ETSU plans to incorporate open-ended problems stemming from government or industry into the proposed curriculum changes. Seven out of twenty-four of the funded programs (29.2%) have done the same, though the area of application to STEM may vary (see Appendix A). Last, for criterion (5), ETSU seeks to incorporate open-source computer languages and modeling into the curriculum as a part of the proposal. Compared to the other programs, five out of twenty-four of the funded programs (20.8%) are seeking to something similar (see Appendix A). Having analyzed these five criteria, we see there is significant overlap between East Tennessee State University's proposal and four of the already funded programs, namely: Massachusetts-2, Colorado, Virginia-1 and Washington (see Appendix B). It is significant to point out that all four of these states rank 18th and above in Proficient test scores, and 21st and above in Basic test scores, both for 8th grade mathematics in 2013 (see Appendix C) [4]. Therefore, we find it necessary to directly compare ETSU's proposal with these four states.

Massachusett-2 (MA-2). (See Appendix B). "Research on the Development of Computational Systems Thinking in Middle School Students Through Explorations of Complex Earth Systems" is a proposal that has been determined to share similar characteristics with ETSU's proposal on four of the defined criteria: (1), (2), (3), and (4). The overall goal of MA-2 is to "develop, implement, and study an innovative intervention that integrates computing into an 8-week Earth systems curriculum and supporting resources." It is a type 1 Exploratory Integration proposal that, to date, has received $1,799,981 in NSF funding [9]. MA-2 targets only 8th grade science classes in Massachusetts, while ETSU will be targeting a broader range of age groups with an emphasis on mathematics. Nevertheless, the age groups overlap. The most significant area in which MA-2 and ETSU's proposal overlap in the the range of influence of the proposal. MA-2 targets fifteen 8th grade teachers across three MA school districts over three years. Recall that ETSU's proposal is similarly targeting twelve mathematics teachers in three school districts of TN. MA-2 will affect about three times as many students as ETSU's proposal. Perhaps the most interesting way in which these two programs compare is that they both are applying real-world scenarios using STEM+C. MA-2 aims to develop skills in the areas of national interest and safety, whereas ETSU's proposals is aimed at business and industry. Both will present real world situations and have students solve complex problems pertaining to these situations. Keeping TN's national test scores in mind, it is interesting to discuss MA's. For 8th grade mathematics scores (that were at or above Proficient), Massachusetts ranked first out of 52. The statewide average test score for Proficient in 2013 was 301, with the national average being 284 [4]. Similarly, Massachusetts ranked first out of 52 for 8th grade mathematics test scores that were at or above Basic (see Appendix C). Compared with Tennessee's rank, perhaps one can conclude that Massachusetts' mathematics education is worth imitating.

Colorado (CO). (See Appendix B). "Research on Effects of Integrating Computational Science and Model Building in Water Systems Teaching and Learning" overlaps on four of the defined criteria: (1), (2), (3), and (5). The theme of this program is that, in order to "achieve model-based reasoning in environmental science, a student needs to concurrently develop more sophisticated computational reasoning" [9]. This is a Type 1 Exploratory Integration proposal that has received $2,199,999 in NSF funding [9]. ETSU's proposal is significantly similar to CO's program in that the targeted age group for the STEM+C integration is mainly directed at high school students. Though CO is nonspecific in the age range detailed on publicly accessible sources, high school students are the intended beneficiaries of the implementation of STEM+C. Like in MA-2, that the application of real-world scenarios is a crucial component of the CO proposal. CO's proposal has done this by "integrating authentic, place- and data-based learning as high school students build and use physical, mathematical and conceptual models" in environmental science" [9], whereas ETSU's project is aimed towards using mathematics and modeling in areas of business and industry. The similarity is still striking in that computational modeling is prevalent in both. Finally, both ETSU's and CO's proposals seek to introduce computer languages and integrate computer modeling into the curriculum. In CO's specific professional development (see Appendix B), it states that students will develop the "ability to use computational tools to develop models, analyze data, produce data visualizations, and identify key trends" [9]. To reiterate, the publicly-accessible information on CO's program does not specify specific computer languages (unlike ETSU's proposal). Nevertheless, the use of computational modeling remains a prevalent theme. It is important to note a striking difference between the two proposals: criterion (4). CO's proposal is significantly larger, directly impacting four times as many students, and twice as many teachers, across four different states across the country (see Appendix A). Finally, in terms of national performance (again for 8th grade mathematics scores), for scores that were at or above Proficient in 2013, Colorado ranks 6th, and for scores at or above Basic in the same year, Colorado ranks 21st.

Virginia-1 (VA-1). (See Appendix B). "Integration of Environmental Chemistry and Computing to Advance Evidence-based Reasoning, Problem-Solving, and Computational Thinking in Middle School Students" met all five of the specified criteria. The overall goal of this program is to "learn about chemical systems, as well as key concepts such as equilibrium and reaction rates, through interacting with models as they are represented visually and about [critical thinking] through modifying and adapting the code to better represent aspects of the chemical systems" [9]. VA-1 is also a Type 1 Exploratory Integration, and it has received $1,250,000 in MSF funding to date. The targeted age range of this project is middle school students, though nonspecific. This ultimately overlaps with ETSU's targeted age range and is significant because ETSU's proposal hopes to start the integration process in the middle school grades and continue the development of STEM+C skills into high school. Again, a major component of VA-1, and of ETSU's proposal, is that the programs are centered around an application of a real-world scenario and trying to solve problems within that context. VA-1's program does this from a chemistry standpoint and has embedded the computational and problem solving aspects of STEM+C into the existing chemistry standards (see Appendix B). ETSU's proposal does this in a very similar way, but with mathematics standards for classes like Algebra I and II. Both programs wished to achieve these goals by integrating computer languages and modeling into the curriculum. As stated above, VA-1 ultimately seeks to teach students how to code useful models for systems and situations in chemistry, and while the targetd discipline differs between the two proposals, the methods and pedagogy would nevertheless align. One additional overlap of note not covered in our five criteria is that each of these proposals operate in direct partership with a state university (in the case of VA-1, with Virginia Polytechnic Institute and State University, as well as the University of Texas). Virginia ranked 18th out of 52 in 8th grade mathematics scores that were at or above Proficient in 2013, and ranked 20th out of 52 in 8th grade mathematics scores that were at or above Basic in 2013 (see Appendix C). Virginia's average test score was 288 (four points above the national average), while Tennessee's average test score was 278. Considering the close physical proximity of these two states, this is a notable contrast in mathematics performance.

Washington's (WA). (See Appendix B). "Research and Design of a Curriculum Authoring System for Computational Project-Based Learning Units in Education" met all five of the specified criteria. The overall goal of this program is to "[advance] the objectives of the STEM+Computing Partnership (STEM+C) program by seeking to enhance knowledge on new approaches to integrating computing into STEM teaching and learning" [9]. WA, like our other discussed proposals, is a Type 1 Exploratory Integration proposal, and it has received $1,500,845 in NSF funding to date. WA targets both middle and high school students, and the range of influence between the two is nearly identical. WA targets 15 teachers and 300 students from Technology Access Foundation Academy (TAF), an official partner of the proposal. Additional partners include a state university (the University of Washington Institute for Science and Math Education) and Inverness Research. WA's proposal is based upon project-based learning (recall, PBL "is a teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an engaging and complex question, problem, or challenge" [3]). This, obviously, bears similarities to ETSU's application-based approach. Washington was ranked 7th out of 52 states who were at or above Proficient in 8th grade mathematics in 2013, and as for the states at or above Basic, Washington ranked 13th (see Appendix C). Washington's statewide national test score average was 290 [4].

Opinions

Written by Erika Hale.

Exploratory Integration is a excellent place to start when introducing a new idea into an area. It clearly states on the NSF web page that "Exploratory proposals should be consistent with the Early Stages and Exploratory type of research and development in the Common Guidelines for Educational Research and Development" [9]. Once ETSU completes the exploratory integration process and thoroughly analyzes the results, more information about our community's capabilities of integrating computing into the STEM curriculum will be available. ETSU has designed a detailed plan and attainable goals for the three year maximum allowed for exploratory integration grants. We expect the efforts to be well received in the community and for the impacts to be positive.

ETSU is focusing on integrating computing into STEM curriculum in 6th-12th grade classrooms. 62.5% of the funded programs previously mentioned fall within this interval. This is a wide, but logical, academic level range to include in this proposal. In our classrooms, sixth grade students have been introduced to computers, though not in any kind of extensive way. By the end of a student's sixth grade year, they have had some form of typing instruction, usually via an introduction to Microsoft Word and/or PowerPoint. Throughout the remainder of the student's public education, little more than this is covered. By the time the student has graduated, it's likely they may have *heard* the term 'computer science' but have never experienced a real introduction to it, let alone ever worked with a computer language. A recent study showed that approximately 30,000 students graduate from college with an Associate's degree in computer science [2], 40,000 with a Bachelor's degree, 17,000 with a Master's degree, and 1,300 with a Doctoral degree, totalling around 88,000 computer science graduates annually. However, there are on average 144,500 annual job openings in computer science fields. That's a 56,000 graduate deficit for what's needed. This could be because there in not enough interest in the computer science field for the students entering college. Currently, the unemployment rate in Tennessee in 6.0% [3]. That's not much higher than our national unemployment rate of 5.5% [3]. If we were able to create more of an interest in computer science before students entered college, this unemployment rate could potentially be affected dramatically. In order pique an interest in the students, they must be introduced to the material, and introducing computer science at a young age can make the transition seem smooth and non-intimidating. Integrating computer science into the STEM curriculum can give the students a deeper understanding to the other math and sciences they are enrolled in, and by the time the student enters high school, they will have developed a modest proficiency in at least one computer language.

Project-Based Learning (PBL) is perhaps one of the most beneficial learning types used in math and science curriculums. In PBL, students are given the opportunity to work on real-world, application-based problems. MIT professor, computer scientist, an mathematician Seymour Papert argues that such problems act as a primary motivation for students [1]. An application-based approach helps circumvent (and immediately answer) the all-to-familiar cries of "When will I ever use this?" and helps build student interest in the content and student engagement in solving problems. By building up a genuine interest in the content, knowledge retention would increase, and an argument can be made that test scores would in turn rise. Indeed, the four states we closely examined all employed application-based learning, and these four states demonstrate much higher test scores than Tennessee.

ETSU's proposal details the need to introduce students to a computer language. As real-world problems are a primary focus of this proposal, and the focus of these problems is on business and industry, the need for learning a computer language becomes evident. Areas

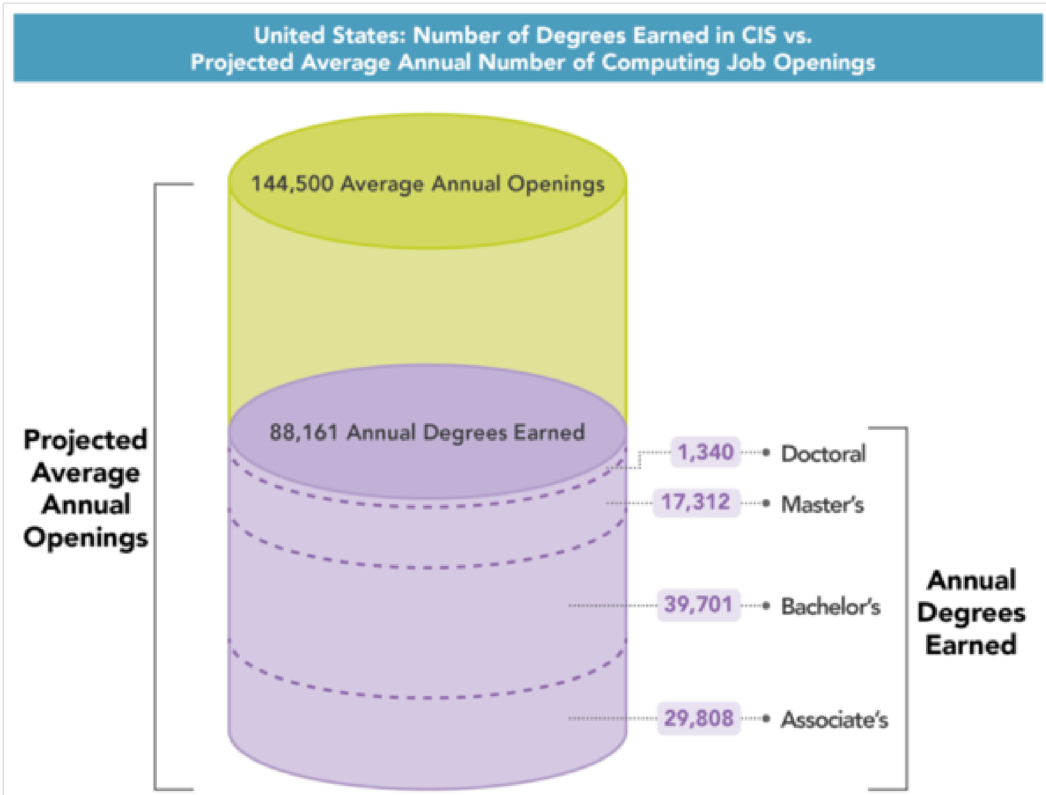

Figure 1: United States CS Degrees vs. Job Openings

of business and industry often find themselves working with "big data", where it becomes virtually impossible to work problems by hand, emphasizing the need for computational software and computer languages. But in order to do so, students must have access to a computer, which can be an issue for low-income schools, thus putting them at a disadvantage for implementing such a curriculum. In the case of the schools officially partnering with ETSU, the majority are eligible for Title I funding, and are therefore low-income schools. Fortunately, devices such as the Raspberry Pi have made it possible for low-income schools to have cheap access to computational software, and in addition, they do not require much physical space; a Raspberry Pi is only slightly larger than a credit card and prices start at

$35. Each comes equipped with a Broadcom, ARM-compatible CPU and GPU, with CPU speeds ranging between 700 MHz and 1.2 GHz, and on-board memory ranging from 256 MB to 1 GB. The Rasperry Pi also accepts expandable memory via an SDHC or microSDHC, where the operating system and any other programs can be stored, and also contains 1-4 USB slots, HDMI, and audio out, with the option of Ethernet, WiFi, and/or Bluetooth. Each is provided a download for Arch Linux, and it promotes Python as the main programming language (though other OSes and software can be used) [6].

Conclusion

East Tennessee State University's "Integrating Computing into the Traditional Curriculum in Mathematics" proposal appears on the right track, bearing many similarities to numerous NSF-funded proposals across the U.S. In particular, four of these proposals (Massachusetts' "Research on the Development of Computational Systems Thinking in Middle School Students Through Explorations of Complex Earth Systems", Colorado's "Research on Effects of Integrating Computational Science and Model Building in Water Systems Teaching and Learning", Virginia's "Integration of Environmental Chemistry and Computing to Advance Evidence-based Reasoning, Problem-Solving, and Computational Thinking in Middle School Students", and Washington's "Research and Design of a Curriculum Authoring System for Computational Project-Based Learning Units in Education") are of significance, as they parallel ETSU's ICTCM proposal to the greatest degree, and each exists in a state performing significantly better than Tennessee in terms of state and national test scores. It is our opinion that such a program implemented in Tennessee would serve to raise test scores, increase STEM competencies, and better prepare students to enter a modern workforce increasingly reliant on computer software.

References

[1] Diane Curtis. Project-Based Learning: Real-World Issues Motivate Students. [Online; accessed 07-April-2016].

[2] na. Computer Science in US Secondary Schools. [Online; accessed 03-April-2016].

[3] na. Economy at a Glance: Tennessee. [Online; accessed 03-April-2016].

[4] na. How Are States Performing? The Nation's Report Card. [Online; accessed 03-April-2016].

[5] na. Science, Technology, Engineering and Math: Education for Global Leadership. [Online; accessed: 19-February-2016].

[6] na. What is a Raspberry Pi? [Online; accessed 07-April-2016].

[7] na. STEM Education in Southwestern Pennsylvania, 2008.

[8] na. A Report from the Committee on STEM Education National Science and Technology Council. [Online; accessed 19-February-2016], 2013.

[9] na. STEM + Computing Partnerships (STEM+C), nd. [Online; accessed 25-January-2016].