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Computer Science and Computational Thinking Across the Early Elementary Curriculum (Work in Progress)

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In 2016 Amazon announced an extensive search to identify a home for its second headquarters, HQ2. Our city, Dallas, TX was near the top of the list for most of the competition. However, when the final choice was announced two years ago, Dallas lost to Washington, D.C. and New York City. According to the Dallas Mayor, who was an active member of the proposal team, a major reason our bid failed was the lack of a well-trained technology workforce and lack of technology education in the local schools [1]. A year earlier Southern Methodist University (SMU) started working with a local Independent School District (ISD) on a statewide grant to increase the number of teachers in their district who are certified by the state to teach computer science (CS) at the high school level. As an outcome of our first grant partnership, we developed a proposal to the National Science Foundation CSforAll: RPP program [2]. We met several times over six months to develop a pilot program that we planned to base the grant upon prior to writing the grant. As a result, this past August our proposal was funded (NSF 2031515). This paper describes our pilot program and some initial findings of the project thus far.

CSforAll:RPP

The CSforAll:RPP program is intended to promote programs to increase the CS literacy of K-12 students. CS is an engineering field critical to the 21st Century workforce. A growing number of CS skills are foundational to academic success today [3]. Most engineering schools like ours have a CS department that teaches computer hardware design and software design. The RPP component refers to Research Practitioner Partnership. RPPs are practical partnerships between education researchers and practicing educators. They are considered *practica*l because each partner has strengths that are complemented by the other. Education researchers are versed in current theory and effective practice in education. Practitioners have deep intuitive knowledge of their constituents. They understand student abilities, likes and dislikes better than researchers [4]. RPPs can develop and test practical solutions to educational issues like the desire to improve access and interest in CS. We developed an RPP between SMU and the ISD. We began our partnership with the ISD two years prior to the grant award.

The partnership began with a statewide WeTeach grant that designated SMU to be a provider of CS teacher professional development (PD) to increase the number of teachers in the state with credentials to teach computer science. At the beginning of the WeTeach grant, only 23 teachers in the state were certified by the state to teach CS [5]. Very few schools were offering CS classes, and most of those few classes were being taught by unqualified teachers. The WeTeach grant program lasted for three years and resulted in over 300 teachers taking and passing the state certification exam. During the last year of the program, our university supported 30 teachers. Ultimately, 25 teachers completed the 60 hours of PD for the project, 10 of them came from our partner ISD.

Both the district and SMU benefited from our work together. The district benefited by being able to bolster their strategic plan to increase CS throughout their district. Their plan was to create a CS pipeline of curriculum and courses throughout their K-12 programs. At the time, they were in the process of implementing programs at the middle school and high school to achieve their goals. One of their stumbling blocks was having enough qualified teachers to implement the program. Due to the WeTeach Grant, they now had enough certified teachers to implement their middle and high school plans. The university benefited because we had found a willing partner with a common interest: increasing the number of effective qualified CS teachers. Creating more CS teachers dovetails with our goal to promote engineering education in K-12 schools. Our next venture was to seek funding for a bigger more directed project. The CSforAll:RPP grant was custom written for us. There are four levels of funding under this grant Small, Medium, Large and Research. We wrote for a small two-year grant because we are initiating our RPP. We hope to scale up to a medium grant in the next round.

Pilot Program

To prepare for the grant we created a pilot project for the last link in the pipeline for the district's strategic plan, the elementary schools, K-6 grades. There is not as much research in CS in elementary education as in middle and high school CS education [6]. There are many reasons for this. Some are clearly age related; small hands have trouble with adult keyboards, and young minds have trouble reading and conceptualizing ideas like computer science and computation thinking. Nevertheless, we developed a teacher PD in CS for elementary content teachers at two elementary schools. These schools have been designated "Schools of Choice for Computer Science" (SOC) in the district. Theoretically, the curriculum at the schools should integrate CS into all academic content areas: math, science, language arts, and social studies. We offered the PD to all the teachers from the two elementary schools.

The pilot consisted of a two-part PD: 1) a one-week summer intensive PD, and 2) a practice unit taught by the teachers in the fall following the summer training. We based this on research in effective PD that recommended that teachers not only have a learning event, but also have an opportunity to put what they learn into practice [7]. The district paid the teachers to attend the summer PD with the assumption that the teachers would develop and implement a CS curriculum project in the fall. Although the teachers were paid, participation in the program was voluntary. The summer PD was divided into two main sections: learning and planning. The learning session lasted two days of the PD. The first day we discussed the definition of CS, explained the pilot project, introduced everyone, and discussed the research on best practices and theoretical outcomes of CS in content classrooms. During the second day, the teachers had the opportunity to explore CS programming software and manipulatives. We had a wide variety of software and hardware for them to explore, because sixth grade students are very different developmentally and physically from first graders. They looked at Scratch, Scratch Jr. and Alice and other block coding resources, and they played with robots, drones and microcontrollers [8, 9, 10]. During the last three days they planned a CS lesson in their content area. They were grouped together during this activity by the grade level they taught. The lesson they created was the lesson that they would teach in the fall to their classes. The CS specialist teachers attended the PD and acted as partners to support the teachers in their planning.

The summer PD happened in July. Twelve teachers attended, 5 from each of the K-6 schools of choice (SOC) and 2 from other elementary schools. The teachers represented a variety of grade levels and content disciplines. According to the exit survey, most of the teachers valued the experience. Most of the teachers were happy to comply with the conditions of the project and developed curriculum projects for the fall. Most appeared to be genuinely excited about teaching their content in a new way. However, two of the teachers at the end of the PD were not yet comfortable or willing to teach their project to their students. At the end of the PD several of the teachers were willing to commit to dates when they would teach their units to their students so that we could observe them.

At the end of the workshop we reviewed some of the curriculum that was produced by the teachers. The curriculum varied greatly in quality and completeness. Some of the curriculum simply substituted technology for pen and paper work. One Language Arts teacher developed some lessons with Sphero robots to show the Hero's Journey. She used the Spheros to follow the typical rising and falling of the plot of the journey. The prior lesson had the students use pencil and paper to plot and label the rising and falling plot. Another CS curriculum seemed to use computers and their computing power in a transcendent way. The teacher developed a CS curriculum unit around the Iditarod Dogsled Race in Alaska. She was very excited about the project and pulled another teacher into the development of the curriculum. She did not feel comfortable building the curriculum alone. The two teachers created a math and social studies CS curriculum project around the logistics for a dogsled team in the race. They created lessons on budgeting for the weight on the sleigh and the cost of supplies. They also brought in potential hazards that could happen along the route that the students should consider. We recognized this as like the Oregon Trail software program developed in the 1970s [11].

Results of the Pilot Program

2 At large teachers said they completed CS curriculum, but no accountability
2 SOC teachers completed a several day curriculum project
1 SOC teacher had the CS teacher teach the curriculum unit
1 SOC teacher team-taught the curriculum unit with the CS teacher
2 SOC teachers completed single day CS activities in their classes
2 SOC teachers team taught the curriculum unit with each other
<u>2 SOC teachers did not attempt any CS curriculum activities</u>
12 teachers attended PD

Table 1

The coaches were at the two CS SOC sites and observed the teacher's CS curricular units. The two teachers from other elementary schools (At large) were not observed, but reported that they attempted their CS curriculum units. We did not follow-up to authenticate what they did to satisfy the CS teaching requirement. We had hoped that all the teachers would have developed a full week (5 days for at least 1 hour a day) of CS activities to teach an entire curriculum unit using computers or computational thinking. Only two of the teachers attempted to teach the curriculum unit that they designed for their class on their own. Two other teachers used their CS curriculum in their classes, but leaned heavily on the CS teacher to deliver all or most of the content. Two other teachers worked together to develop a unit and taught the unit together in their classes (the Iditarod Unit). Two other teachers did single day CS activities in their classes in fulfillment of the curriculum requirement (See Table 1). The researchers were invited to observe one class during a CS curriculum unit, and interviewed the coaches about the other curriculum units.

The CS teacher roles at their schools were different than we expected. We thought the CS teachers were partners with the content teachers. We thought their job was to help the content teachers integrate CS methods and strategies into their content areas. Instead they seemed to be teachers with a specific subject specialty who taught within the CS silo. The CS teachers were designated as elective teachers with the music teacher, and PE teachers. Their job description included pull-out and push-in activities. In grades K-3 the CS teachers were expected to push-in to these classes with CS lessons. In grades 4-6, the teachers pulled-out students to train them in CS lessons. They provided us with their curriculum plan early in the fall after the summer teacher PD. The curriculum was focused on providing instruction on the use of computers and software programs. The typical lessons included instruction on how computers work, keyboarding, searching the Internet, and using computers for word processing and quizzes. The curriculum they planned did not integrate content knowledge from the content classes like math, science, language arts or social studies. Their duties also included "Other Duties as Assigned" which included supervision, proctoring tests, covering classes for content teachers, and sometimes providing disciplinary supervision of students. The content teacher's expectations of the CS teachers was also unexpected. Most of the teachers used the CS teachers to cover their classes so that they could have planning time. When the CS teachers pushed-in to the K-3 classes the teacher typically did not participate in the classroom activities. Instead, they graded papers and sometimes left the room completely. During the pull-out periods the content teachers did not follow their students to the CS teacher's classroom for the lesson.

We used what we learned during this pilot to better organize, and incentivize the participants in the grant plan.

Writing the Grant

We began preparing to write the grant over six months in advance of the due date. We understood that the partners had a great deal to learn about each other. We created an Executive Committee made up of researchers from our university and two administrators from the ISD—the Deputy Superintendent, and the STEM and School Libraries Coordinator. We discussed many things during several meetings including needs, plans, budgetary and legal constraints of the district. And, the research constraints like consent forms, IRB approvals, meaningful measurable variables, and research protocols. The meetings were lively and filled with information sharing, insights and compromises that lead to a common understanding of each other and ultimately to a focused plan.

We learned that the district's operating philosophy and vision came from an interesting mix of educational research and business theory. Both the researchers and the ISD Administrators valued processes for continuous improvement. On the research side, we focused on the Design Based Implementation Research (DBIR) framework to promote continuous improvement, while the district had adopted a business framework [12]. The ISD follows the Baldrige Education Criteria for Performance Excellence Framework [13]. The Baldrige Framework follows a systematic approach to school improvement. The framework provides strategies and resources to evaluate and improve the overall health of an organization. Fortunately, both theoretical frameworks lead to similar processes that we could all agree upon. The ISD also had a corporate culture. The researchers often emphasized the voluntary nature of the project with regards to the teacher's participation, and were met with something like, "If they are being paid to do something, they do not have a choice." Nevertheless, they did agree that we should pick the teachers who are most likely to comply with the requirements for the proposal. As researchers we also wanted to narrow our research as much as possible, against a push from the ISD to be as inclusive and encompassing as possible. Ultimately, the ISD agreed to a focus the project on 16 teachers from two grade levels at the two SOCs. They hoped for more teachers to be involved, and were surprised by how little $300,000 grant funding could support. We used a logic model to plan the grant. Both parties were familiar with logic models to identify activities, and their expected inputs and outputs [14].

The proposal addressed numerous perceived issues that we faced during the pilot. The proposal identified CS coaches at each school. They are critical participants in the project. They are the CS teachers at the CS SOCs. We want to elevate their title and responsibilities through this grant to make it explicit that their primary job is to facilitate content classes in integrating CS, not to teach stand-alone classes with content exclusive to CS. During the grant, we will train the CS teachers on being coaches to the content teachers, and we will work with their principals to allow them to act more like coaches rather than CS content teachers. The coaches will also be an integral part of the research team. They have better access to the teacher's classrooms and will be able to observe the teachers teaching their CS curriculum units. They are expected to provide a third-party reflection on the outcome of the curriculum units. They are also expected to actively support the teachers in the development of the curriculum planning during a summer PD and throughout the semester. The teachers are expected to attend a 5-day summer PD like the pilot PD. However, the PD will have more explicit expectations. They will be paid extra for attending the summer PD, and paid separately to teach the curriculum that they design in each semester. This will increase their incentive to actually deliver what they plan in the summer. They are also expected to attend a Professional Learning Community (PLC) of all the teachers participating in the grant (16 teachers) once a month during the school year for an hour and a half. During the PLC meetings the teachers will share their curriculum ideas and their reflections on what worked during their curriculum presentations to their students. Both the coaches and the teachers will be paid for the extra duty.

CSforAll:RPP

Our project was approved for funding in August 2020. The project is an early stage Research Practitioner Partnership (RPP). It is a two-year grant. The plan is to use this grant to initiate the RPP with the ISD, start work on the research agenda, and prepare to scale up the project into a medium size three-year grant.

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