2020

Introducing Coding Into Teacher Education: An Interdisciplinary Robotics Experience for Education and Engineering Students

Jennifer Kidd
Old Dominion University, jkidd@odu.edu

Krishna Kaipa
Old Dominion University, kkaipa@odu.edu

Sam Sacks
Norfolk Public Schools

Lilian Almeida
Old Dominion University

Original Publication Citation

Kidd, J., Kaipa, K., Sacks, S., & de Souza Almeida, L. M. (2020). *Introducing coding into teacher education: An interdisciplinary robotics experience for education and engineering students*. Paper presented at the Society for Information Technology & Teacher Education International Conference 2020, Online.

Introducing Coding into Teacher Education: An Interdisciplinary Robotics Experience for Education and Engineering Students

Jennifer Kidd, Krishna Kaipa, Old Dominion University
Sam Sacks, Norfolk Public Schools
Lilian Almeida, Old Dominion University

Despite nationwide mandates to integrate computer science into P-6 curriculum, most P-6 preservice teachers (PSTs) are not exposed to coding or computational thinking during their professional preparation, and are unprepared to teach these topics. This study, conducted as a part of an NSF-funded project, explores a teacher preparation model designed to increase PSTs' coding knowledge and coding self-efficacy. PSTs in an educational technology course partnered with engineering undergraduates (EUs) in a computational methods course and worked side-by-side on robotics activities to develop skill and confidence with basic programming concepts and block coding. Students utilized experience gained from these interdisciplinary partnerships to lead robotics activities with fifth and sixth grade students (FSGs) in an after-school technology club. Findings from quantitative studies suggest that the implementation of the approach resulted in a significant increase in both PSTs' coding knowledge and coding self-efficacy. Qualitative studies revealed that most PSTs' and EUs' perceived value of the project was positive.

Purpose

In the past few years, dozens of states have passed new laws and regulations promoting computer science. As of 2019, more than half of the states had established K-12 Computer Science standards (State of Computer Science Education, 2019). A recent report on the status of computer science education in the United States asserts that "computing is changing every part of our lives, from how we interact with each other to how we do our jobs" (State of Computer Science Education, 2018). Furthermore, computational thinking (CT) has been recognized as a fundamental skill to problem solving and teachers are being asked to include CT in all content areas, in addition to computer science and other STEM related classes (Cherrez, Jones, & Seweers, 2019). Virginia was the first state to require computer science education (Sawchuck, 2017). Its mandatory standards emphasize computational thinking (CT) and coding, and were designed for K-8 integration. Despite these mandates to integrate computer science into P-6 curriculum, most P-6 preservice teachers (PSTs) are not exposed to coding or CT during their professional preparation, and are unprepared to teach these topics (Hsu et al., 2011). If states are determined to teach computer science at the elementary level, they must develop teacher preparation programs to equip teachers to do so (Grover & Pea, 2013).

This paper presents research on an NSF-funded project focused on the development and evaluation of a model for integrating coding into P-6 teacher preparation in Virginia. The model brings teacher educators and undergraduate engineering faculty together to foster cross-disciplinary learning that has benefits for both disciplines. While PSTs and education faculty need exposure to engineering and computer science, engineering undergraduates (EUs) need experience working in interdisciplinary teams. The standards issued by the Accreditation Board for Engineering and Technology (ABET) include the ability to effectively function and collaborate on teams as well as to communicate with a range of audiences (ABET, 2020), since the solutions to today's most challenging engineering problems require expertise from multiple fields (Tomek, 2011). Research suggests engineering students often fail to recognize and value contributions from other fields (Richter & Paretti, 2009) and can benefit from interdisciplinary learning experiences during their preparation (Richter, Paretti, McNair & Borrego, 2009).

In Spring 2019, PSTs in an educational technology course, offered in the College of Education and Professional Studies at Old Dominion University, were partnered with EUs in a computational methods course, offered in the College of Engineering and Technology at the same University. Early in the semester, the students worked side-by-side on robotics activities to develop skill and confidence with basic programming concepts and block coding. Starting in the sixth week, the undergraduate students led fifth and sixth grade students (FSGs) who were recruited to participate in an after-school technology club, in similar activities. The robotics project spanned five weeks and culminated in the creation of bio-inspired robots and a showcase event for the children's families. The intervention was intended to enhance PSTs' skills, confidence, and motivation to integrate coding into their future classrooms and to enhance EUs' interdisciplinary collaboration skills.

Perspectives

This research draws on constructionism (Papert, 1980) and social constructivism (Piaget, 1985; Vygotsky, 1980) in the design of the intervention, and social learning theory (Bandura, 1993) for evaluating its impact. For the intervention, education and engineering students collaborated to learn and teach robotics. Papert (1980) believed that children learn best by creating physical representations to explore concepts and relationships. He saw the promise of teaching CT through a constructionist approach, where students develop programming expertise through creation of artifacts. Robotics enables students to construct three-dimensional artifacts they are able to control via coding. Collaboration between EUs and PSTs relied on small-group learning. According to social constructivism, cross-disciplinary collaboration prompts students to experience new and different perspectives as they build knowledge (Piaget, 1985).

The project's evaluation focused on students' knowledge and attitudes, exploring what the students learned, how they learned, if they feel confident about what they learned, and whether they found the learning valuable. Bandura's social learning theory suggests that self-efficacy, or "people's beliefs about their capabilities" (p. 118), is developed from social experiences and self-perception, and is influential in determining outcomes. Teacher self-efficacy has been linked to many important teacher characteristics and student outcomes, including willingness to adopt innovative teaching strategies (Tschannen-Moran & McMaster, 2009), intention to use technology (Teo, 2009), and improved student performance (Caprara et al., 2006). Several factors have been found to contribute to teacher self-efficacy, including content knowledge (Swackhamer et al., 2009), belief in a subject's importance (Yasar et al., 2006), and successful lesson implementation (Fogg-Rogers et al., 2017; Rich et al., 2017). The study in this project explored whether learning and teaching robotics can contribute to PSTs' coding knowledge and self-efficacy, and whether or not both groups of college students found the interdisciplinary collaboration beneficial.

There is growing evidence that robotics improves elementary students' STEM learning (Rogers & Portsmore, 2004) and CT (Ardito & Czerkawski, 2019; Bers et al., 2014). A few studies have examined PSTs' implementation of robotics lessons (e.g. Kim et al., 2017). However, investigations of how robotics influences PSTs' coding skills are only beginning to appear (Jaipal-Jameni & Angeli, 2017). This points to the need for more studies exploring the links between robotics-based pedagogy and PSTs' ability and interest in coding. More broadly, research is needed to understand how teacher education can prepare PSTs to competently and confidently integrate coding into P-6 instruction.

Among multiple possible approaches, partnering PSTs and EUs has been considered a promising alternative to answer this question. Bers and Portsmore (2005), for example, investigated a partnership between these two specific groups as the students conceived, developed, implemented, and evaluated STEM curriculum using robotics and the engineering design process. The researchers noted how successful and powerful the PSTs-EUs partnership can be and its "tremendous potential to offer learning experiences to both sets of students" (p.72). While the PSTs in the study were able to consider possible uses of technology in their classes, EUs had the opportunity to engage in a real engineering experience and think about clients' demands and technical constraints. Additionally, they gained insights into the educational system and the factors involved in incorporating technology into the classroom. The collaboration between PSTs and EUs was also promoted as part of a broader multidisciplinary initiative described by Pinnell, Rowley, Preiss, Blust, and Beach (2013). In this initiative, the benefits of a collaborative relationship between a school of engineering and a school of education were evident in the interest of preparing teachers better equipped to incorporate engineering design and innovation into their classroom. Preliminary results of the research investigating the partnership between PSTs and EUs here described represent the first steps in answering the following questions:

1. How did collaborating with EUs to learn and teach robotics impact PSTs' coding knowledge and coding self-efficacy?
2. What were PSTs' and EUs' perceptions of the value of the project?

Methods

Participants & Context

Eight PSTs in an educational technology course and twenty EUs in a computational methods course participated in an interdisciplinary collaboration (see Table 1). Each PST was partnered with approximately three EUs to form teams that engaged in five collaborative sessions over the course of one semester. The first two collaborative sessions were held on campus and were intended to help both groups of undergraduate students learn about coding and robotics. The final three collaborative sessions were held at a local school in the context of a ten-week after-school technology club for FSGs. The PSTs ran the after school club alongside their instructor, and were present for all ten meetings of the club. The EUs were only present for the club meetings that focused on robotics.

Table 1. Participant Demographics

Group	Gender		Race					Age Range
	Male	Female	White	Black	Asian	Hispanic	Mixed Race	
PSTs	0	8	5	2	-	1	-	20-44
EUs	15	5	15	2	1	2	-	20-36

The relationships between the PSTs and EUs within their interdisciplinary teams were intended to be dynamic and mutually beneficial, with the undergraduate students alternating between the roles of mentor, mentee, and co-learner, depending on the activity and expertise of the individual team members. In the first collaborative session, EUs were tasked with teaching the PSTs about Sphero robots and how to use a loop in block programming. In the second collaborative session, PSTs and EUs were asked to engage as co-learners, exploring resources they had not previously used, LEGO WeDo kits, to build and code an animal-inspired robot. Following these collaborative learning opportunities, each team was required to make a plan to engage FSGs in similar robotics activities and add details to a 5E lesson plan (Bybee et al., 2006) developed by the instructor.

The final three collaborative sessions occurred during the after-school club. One EU from each team participated in each session. The PST and her collaborating UE team member were partnered with two FSGs for each session. The first two sessions mirrored the earlier collaborative sessions on Sphero and LEGO WeDo. The third collaborative session occurred during a bio-inspired robotics project. Each PST led her team of two FSGs to design, build, and program an animal-inspired robot using household (e.g. cardboard boxes, straws) and technical components (servo motor, speaker, LEDs). The bio-inspired robots were controlled with Arduinos coded using mBlock to create mobility, sound, and light. During the final collaborative session, the EU from each team helped design, build, and code a mechanism to generate the robot's movement.

Measures

This research utilized mixed methods (Creswell & Clark, 2007). Two quantitative pre-/post- instruments were used: a survey for assessing PSTs' coding self-efficacy (Rich et al., 2017) and a CT quiz adapted from two established instruments (Shen, 2017; Zur Bargury et al., 2013). Fourteen code-agnostic multiple-choice items and one short-answer question assessed CT concepts (sequencing, looping, variables, conditionals, and debugging) aligned with Virginia's CS standards.

Two qualitative measures were used: undergraduate student reflections and an end-of-course PST focus group. The reflections consisted of open-ended prompts asking students to describe what they taught FSGs during the after-school technology club, the roles they played during the robotics lessons, what they felt most/least confident about, their perceptions of the lessons' successes, and what they learned from the experiences. An hour-long focus group conducted at the end of the semester asked PSTs to describe how they supported the creation of the animal robots. More broadly, it asked them to discuss their interest in coding and engineering, their plans to integrate these subjects in their future instruction, and whether they felt confident in their ability to do so. Finally it inquired whether the PSTs believed coding and engineering were valued by students, parents, and administrators.

T-tests were used to compare participants' pre- and post- scores. Qualitative content analysis (Zhang & Wildemuth, 2009) was used to identify emergent themes related to coding knowledge, self-efficacy, and perceptions of the project. Two researchers identified themes in a selection of student reflections. The themes were compared and reviewed until consensus was reached. All reflections were then coded with the agreed upon themes. The same process was used to code the focus groups.

Results

There was a significant difference in coding knowledge for PSTs' pre- and post- test ($t = -2.553$, $p = .038$). The mean increased from 5.75 ($SD = 2.31$) to 6.88 ($SD = 3.23$). PSTs performed best on items assessing sequencing and loops. They struggled on questions incorporating spatial reasoning, and items assessing conditionals, especially when calculations or comparators were included. PSTs showed the most improvement coding a robot to turn at right angles and using a loop to form a square, activities that were explicitly covered in the Sphero lesson. There was also a significant increase in PSTs' coding self-efficacy from pre-test ($M = 2.65$, $SD = .28$) to post-test ($M = 3.23$, $SD = .96$; $t = -2.824$, $p = .026$).

Six major themes emerged from PSTs' qualitative data (see Table 2). Affective responses (slightly more negative than positive) were most prevalent. Remaining themes described what PSTs learned, how they learned, the roles they played during the lessons, and the value they ascribed to the project and coding more broadly. The data suggests PSTs learned about programming from their engineering partners and from teaching and interacting with FSGs, but did not feel confident with coding, and felt unprepared to lead the robotics activities. Some PSTs discussed taking the lead on coding instruction, but more PSTs reported deferring to engineering partners to explain coding concepts and answer coding-related questions.

Table 2. PST Focus Group & Reflection Themes

Theme	Frequency	Dominant Sub-themes (# of coded instances) & Illustrative Quote
Affective Responses	109	Negative (62): Lack of Confidence (38), Unprepared (18), Unsuccessful (6) "It helped me get a bit more comfortable with the idea of it, but at the same time though, I wouldn't feel comfortable teaching it on my own." "I was not very confident in much of the lesson. I was very unprepared on what information to share and how to share it with my students." Positive (47): Confidence (16), Successful (15), Fun & Enjoyment (9), Partially Successful (7) "I felt really confident in delivering the lesson and my ability to explain the concepts of looping and angles." "I think it was very effective just by how much they progressed in the one session we did with them. They could not make a square when they first came in, but by the end they could make any shape they wanted and put on as many personalized items as they wanted."
What PSTs Learned	65	About Coding (42): How to Code & Control Robot (21), Applications of Coding (10), Underlying Concepts (6), Connection Between Math or Science Concepts & Coding (4), Troubleshooting (1) "I learned from this lesson how to use MBlock and the Arduinos to code things such as movement, lights or even music. I could possibly use those if I decide to teach engineering in my classroom." About Teaching (23): Lesson Preparation (9), Lesson Delivery/Interacting with Students (8), Students' Prior Knowledge of/Ability to Learn Coding (6) "Prep work is very important! Get the most knowledge that you can about a

		lesson and figure out the most effective way to deliver it. Also understand that it's important to just do the best that you can, there's no such thing as perfection."
How PSTs Learned	41	From Engineering Partner (17), Teaching & Learning with Students (16), From Students (3), Prior Knowledge (3), Through Preparation (2) "He taught me concepts about coding that I didn't know before and when I didn't understand them still he would explain them in a different way." "As my student was learning, I was learning. We were putting in random pieces of coding and guessing on what they were going to do."
Importance of Technology & Coding	35	Positive Statements (17), Uncertain About Student & Parent Interest (11), Impact on FSG Knowledge (7) "I feel like it's important to learn at least a little bit of it since everything is now becoming technology based." "Parents seem to want to dial that back. When we're talking to them they're like 'I don't want to go on any kind of technology at home' and stuff, but the schools seem to integrate it a little more"
PSTs' and EUs' Roles During the Lessons with FSGs	32	Engineers Teaching Coding & Technical Content (17), PSTs Actively Teaching Coding (7), PSTs in Support Role (6), PSTs Letting Students Figure it Out (2) "He taught the majority of the lesson because we felt he was better at explaining the concepts. I interjected as necessary."
Perceived Value	28	Overall Project - Positive (20), Negative (8) "[The WoW Club] was very demanding but it was also very rewarding"

The EUs' reflective comments were generally positive (see Table 3). They discussed enjoying their experience with FSGs. The EUs were not consistent on how the project influenced their coding knowledge: some reported the project enhanced their understanding, while others reported little to no benefit. Many EUs reported gaining communication and collaboration skills through interacting with PSTs and FSGs.

Table 3. EU Reflection Themes

Theme	Frequency	Dominant Sub-themes (# of coded instances) & Illustrative Quote
Affective Responses	38	Positive (30) - e.g. Satisfied with Outcome, Enjoyed Interacting with Kids, Confidence "They were very intelligent kids and I enjoyed sharing some engineering information with them. I was glad to see youth interested in science and mathematical aspects of the world around us." Negative (8) - e.g. Lack of Confidence, Difficulty "I felt least confident on how to engage the students with coding."
Development of Professional Skills	22	Interdisciplinary Communication (13), Teamwork or Interpersonal Skills (9) "I learned how to break down complicated problems and how to use simpler terms instead of engineering specific jargon."
Impact on Understanding of Coding	16	Little to No Benefit (7), Enhanced Understanding (6), Reinforced Understanding (3) "Because it was for 5th and 6th grade students, the material was very basic

		so what we were teaching is already an area I am confident in." "I felt like I understand the concepts more because I had to think of it in different ways in order to teach the student."

Overall, although PSTs reported lack of confidence with coding during focus groups, quantitative studies suggest that there was a significant increase in both PSTs' coding knowledge and coding self-efficacy. Most PSTs' and EUs' perceived value of the project was found to be positive.

Discussion & Scholarly Significance

The integration of coding into elementary school standards is new and the effort to prepare PSTs to teach coding is in its infancy. While some research has addressed how to prepare teachers to teach coding, more needs to be learned. This study explored three intertwined approaches to preparing teachers to integrate coding into their future instruction: 1) pairing PSTs with EUs, 2) engaging PSTs in robotics activities, and 3) providing PSTs with opportunities to teach robotics lessons to students. The goal of the intervention was to improve PSTs' coding knowledge and self-efficacy with the expectation that an increase in skills and confidence would enhance the likelihood that PSTs would teach coding in their future classrooms. In addition, the researchers hoped the intervention would have positive benefits for cooperating EUs, reinforcing their coding knowledge, and enhancing their ability to interact with non-technical audiences.

Research on this intervention will continue. Findings suggest that PSTs benefit from interacting with EUs, however, it is not yet clear how to structure these collaborations so that PSTs can gain both coding knowledge, and the confidence to operate independently of their engineering partners. Robotics as a vehicle for promoting CT has documented success and aligns well with Papert's constructivist ideology. It also engages the students in an engineering design process, thereby addressing new state (VDOE, 2018) and national standards (NGSS Lead States, 2013). Moreover, the PSTs reported enjoying the animal robot project and seeing benefits for the FSGs. Nevertheless, the technologies used in the project (Arduino, servo motors, LEDs) represent a significant learning curve, especially when compared to online coding resources like Scratch and code.org. It remains unclear whether physical computing enhances or impedes the development of PSTs' coding knowledge and self-efficacy. The results of this study and prior studies (Kidd et al., 2019; Rich et al., 2017) suggest that engaging PSTs in teaching engineering and computing lessons to elementary students is a promising practice as it led to gains in coding self-efficacy and coding knowledge. The PSTs also reported learning from teaching and interacting with FSGs. However, the PSTs may benefit from direct coding instruction in order to feel adequately prepared to confidently and independently integrate coding in their future P-6 instruction.

In addition to implementation concerns, questions remain about instrumentation. It is unclear whether a quantitative measure of CT is the best tool to assess PSTs' readiness to engage students in coding activities. Isolating and assessing coding concepts in a platform-agnostic measure is challenging. CT skills build on each other. Many items on the developed CS quiz relied on spatial reasoning (Román-González et al., 2017), an ability associated with I.Q. tests. Interestingly, a recent study found that neither PSTs' prior knowledge of coding, their interest in coding, nor their apprehension for teaching coding predicted success with learning coding, but their SAT math, verbal, and writing scores did (Penny et al. , 2019). Most PSTs participating in the study (77%) were able to successfully complete the coding exercise in the coding environment they were taught, however, far fewer (23%) were able to abstract the coding concepts and solve a similar task in a new coding environment. The PSTs in this study expressed frustration moving from one block coding application to another and wanted to learn specific commands associated with each application to teach the students. While familiarity is helpful for coding efficiently, someone familiar with coding concepts should be able to navigate a new block coding platform without significant issue. ISTE (2011) suggests that CT includes dispositional components including confidence dealing with complexity, persistence working with difficult problems, tolerance for ambiguity, and the ability to deal with open-ended problems. PSTs may struggle with these. More work is needed to determine what knowledge, skills, and dispositions PSTs need to integrate coding, and the best measures to assess these competencies.

References

ABET, Accreditation Board for Engineering and Technology. Criteria for Accrediting Engineering Programs (2020). Retrieved from http: https://www.abet.org/wp-content/uploads/2018/11/E001-19-20-EAC-Criteria-11-24-18.pdf

Ardito, G., & Czerkawski, B. The Effects of Gender and Literacy in the Development of Computational Thinking Skills in 6th Grade Students.*Proceedings of the Society for Information Technology and Teacher Education 2019 Annual Conference, Las Vegas, NV*

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational psychologist*, *28*(2), 117-148.

Bers, M. U., Flannery, L., Kazakoff, E. R., & Sullivan, A. (2014). Computational thinking and tinkering: Exploration of an early childhood robotics curriculum. *Computers & Education*, *72*, 145-157.

Bers, M. U., & Portsmore, M. (2005). Teaching Partnerships: Early Childhood and Engineering Students Teaching Math and Science Through Robotics. *Journal of Science Education and Technology*, 14(1), 59-73

Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. *Colorado Springs, Co: BSCS*, *5*, 88-98.

Caprara, G. V., Barbaranelli, C., Steca, P., & Malone, P. S. (2006). Teachers' self-efficacy beliefs as determinants of job satisfaction and students' academic achievement: A study at the school level. *Journal of School Psychology,* 44(6), 473-490.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Sage.

Cherrez, N. J., Jones, T., & Sweers, B. Computational Thinking in Action: Paving the Way for Pre-Service Teachers. *Proceedings of the Society for Information Technology and Teacher Education 2019 Annual Conference, Las Vegas, NV.*

Creswell, J. W., & Clark, V. L. P. (2007). Designing and conducting mixed methods research: Wiley Online Library.

Fogg-Rogers, L., Lewis, F., & Edmonds, J. (2017). Paired peer learning through engineering education outreach. *European Journal of Engineering Education*, *42*(1), 75-90.

Grover, S., & Pea, R. (2013). Computational thinking in K-12: A review of the state of the field. *Educational Researcher, 42*(1), 38-43.

Hsu, M., Purzer, S., & Cardella, M. E. (2011). Elementary teachers' views about teaching design, engineering, and technology. *Journal of Pre-College Engineering Education Research (J-PEER), 1*(2), 5.

ISTE. (2011). Operational definition of computational thinking for K-12 education. Retrieved from http://www.iste.org/docs/ct-documents/computational-thinking-operational-definition-flyer.pdf

Jaipal-Jameni, K., & Angeli, C. (2017). Effect of robotics on elementary preservice teachers' self-efficacy, science learning, and computational thinking. *Journal of Science Education and Technology, 26*(2), 175-192.

Kidd. J., Kaipa, K., Sacks, S., & Rippard, K. (2019, March). 5th/6th Graders and Preservice Teachers Explore Engineering and Coding in a Combined After-School Technology Club/Educational Technology Course. *Proceedings of SITE 2019--Society for Information Technology & Teacher Education International Conference*. Washington, D.C. Association for the Advancement of Computing in Education (AACE). https://www.learntechlib.org/p/207858/

Kim, C., Yuan, J., Gleasman, C., Shin, M., & Hill, R. B. (2017). Preparing Pre-Service Early Childhood Teachers to Teach Mathematics With Robots. Philadelphia, PA: International Society of the Learning Sciences.

NGSS Lead States (2013). *Next generation science standards: For states, by states*. Washington, D.C.: The National Academies Press.

Neary, J. (2016). K-12 Computer Science Standards: Research Support for the Colorado Department of Education. Retrieved from https://www.cde.state.co.us/standardsandinstruction/researchreport-computerscience

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas.* New York, NY: Basic Books, Inc.

Penny, Schugar, Schugar, & Cooke (2019). Can Everyone Code? Preparing Teachers to Teach Computer Languages as a Literacy, ISTE EdTEch conference, Philadelphia, PA, June 23-26

Piaget, J. (1985). *The equilibration of cognitive structure: The central problem of intellectual development*. Chicago: University of Chicago Press.

Pinnell, M., Rowley, J., Preiss, S., Blust, R. P., & Beach, R. (2013). Bridging the Gap Between Engineering Design and PK-12 Curriculum Development Through the Use the STEM Education Quality Framework. Journal of STEM Education, 14(4), 28-34.

Rich, P., Jones, B., Belikov, O., Yoshikawa, E., & Perkins, M. (2017). Computing and engineering in elementary school: the effect of year-long training on elementary teacher self-efficacy and beliefs about teaching computing and engineering. *International Journal of Computer Science Education in Schools, 1*(1), 1-20.

Richter, D., Paretti, M., McNair, L., & Borrego, M. (2009). Assessing student perspectives of interdisciplinary collaboration. In 2009 ASEE Annual Conference and Exposition

Rogers, C., & Portsmore, M. (2004). Bringing engineering to elementary school. *Journal of STEM Education, 5*(3 and 4), 17-28.

Román-González, M., Pérez-González, J-C., & Jiménez-Fernández, C. (2017). Which cognitive abilities underlie computational thinking? Criterion validity of the computational thinking test. *Computers in Human Behavior*, 72, 678-691.

Sawchuck, S. (2017, Nov 21). Virginia Becomes First State to Require Computer Science Instruction. Education Week. Retrieved from http://blogs.edweek.org/edweek/curriculum/2017/11/virginia_mandates_computer_science_learning.html

Shen, Ji. (2017). Transformative Robotics Experience for Elementary Students (TREES)Items-FormA fall2015.

Stanton, J., Goldsmith, L., Adrion, R., Dunton, S., Hendrickson, K., Peterfreund, A., ... & Zinth, J. (2017). State of the States Landscape Report: State-Level Policies Supporting Equitable K–12 Computer Science Education. *Education Development Center*.

State of Computer Science Education. (2018). Retrieved from https://advocacy.code.org/

State of Computer Science Education. (2019). Retrieved from https://advocacy.code.org/

Swackhamer, L. E., Koellner, K., Basile, C., & Kimbrough, D. (2009). Increasing the self-efficacy of inservice teachers through content knowledge. *Teacher Education Quarterly*, *36*(2), 63-78.

Tomek, S. (2011). Developing a multicultural, cross-generational, and multidisciplinary team: An introduction for civil engineers. Leadership and Management in Engineering, 11(2), 191-196.

Teo, T. (2009). Modelling technology acceptance in education: A study of preservice teachers. *Computers & Education, 52*(2), 302-312.

Tschannen-Moran, M., & McMaster, P. (2009). Sources of self-efficacy: Four professional development formats and their relationship to self-efficacy and implementation of a new teaching strategy. The *Elementary School Journal, 110*(2), 228-245.

VDOE. (2018). Science Standards of Learning for Virginia Public Schools. Available at http://www.doe.virginia.gov/testing/sol/standards_docs/science/index.shtml

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Yasar, S., Baker, D., Robinson-Kurpius, S., Krause, S., & Roberts, C. (2006) Development of a survey to assess K-12 teachers' perceptions of engineers and familiarity with teaching design, engineering, and technology. *Journal of Engineering Education, 95*(3), 205-216.

Zhang, Y., & Wildemuth, B. M. (2009). Qualitative analysis of content. Applications of social research methods to questions in information and library science, 308, 319.

Zur Bargury, I., Pârv, B. & Lanzberg, D. (2013). A Nationwide Exam as a Tool for Improving a New Curriculum. Proceedings of ITiCSE'13, (267-272). Canterbury, England, UK