Teaching Teachers to Think Like Engineers Using NetLogo

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Teaching Teachers to Think Like Engineers Using NetLogo
(RTP- Research to Practice paper)

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Abstract

This paper provides a view of 22 K12 teachers' expectations versus the actuality of immersion into an engineering education computer science (CS) project during a Math/Science Partnership (MSP) grant called RAMPED, which was a 16-day, yearlong MSP grant. The CS session using NetLogo was selected for focused examination. NetLogo is a multi-agent simulator that uses the educational Logo programming language and was designed for classroom modeling experience. The research question for the study was, "How do K12 teachers view their skill set of using computer science in their classrooms before, during, and after professional development (PD)?" RAMPED participants spent a total of three days immersed in using NetLogo as a vehicle for learning fundamental computer science principles and engineering applications for K12 classrooms. The authors used a social constructivism approach and examined K12 teacher NetLogo usage in and out of the classroom. The authors also collected the data via K12 teacher surveys and informal interviews. Findings show that the teachers self-reported high expectations of their skillset as well as easy assimilation of NetLogo (but not CS) into their classroom teaching. On a scale from 0 to 5, where 0 is not at all skillful and 5 is extremely skillful, survey pretest results show over 50% at a 3, 4, or 5. Posttest survey results show over 90% at a 3, 4, or 5. After the summer session, NetLogo was useful to 95% of K12 teachers. After an academic year NetLogo follow-up session over 75% of the K12 teachers were satisfied with instruction and support. Over 85% of teachers believed that the workshop "stretched teacher thinking into their classrooms." Teachers’ qualitative comments are included for triangulation. Conclusions include that intense K12 teacher exposure to engineering CS topics (e.g. 24 hours total of a larger PD) is not enough to truly enact meaningful classroom changes (although the teachers did create new activities). Additional support for meaningful classroom change and K12 teacher confidence is necessary. In general, K12 teachers need (and asked for) support in the form of ready to use lessons and documents (e.g. additional activities) along with leader presence to support them in trying their self-created plans situated within the NGSS standards. The actuality of working with NetLogo (and changing functions and code) to present STEM concepts/topics was both invigorating (it was new for the K12 teachers) and frustrating (it was often hard for the K12 teachers to see connections to content) as teachers moved through expectations and actuality. Implications include planning for structured K12 teacher academic year support in implementing CS topics for sustainability in classrooms.

Keywords: Computer Science Education, Computer Science, STEM, K12 Teachers, Pre-Service Teacher Education, Engineering Education

1. Introduction – Research to Practice Paper

Engineering education, and especially computer science (CS) within that realm, is embedded within science, technology, engineering and mathematics (STEM), but K12 classroom practices do not often reflect CS content due in part to teacher skill levels and an efficacy gap. CS can take on many meanings, but at its core, it is the science of problem solving in a computational context, and CS as a skill is challenging (Burrows, Borowczak, Slater, & Haynes, 2012). Most CS university programs prepare software engineers, and as such the subjects are entwined. The distinction between engineering and CS can be blurry if only examining the theory of CS instead of the practical applications. This paper explores the practical application and hence engineering.
As an engineering skill and practice called for in the Next Generation Science Standards, or NGSS, (NGSS Lead States, 2013), problem solving is critical. Thus, the practical and immediate benefits of teaching and incorporating CS in K12 classrooms are the connections to and use of higher order Bloom's cognitive and 21st-century skills. CS requires students to solve problems, design creative solutions, analyze and assess multiple results, collaborate, and finally, present and justify their end products. CS is traditionally presented as a stand-alone subject in current pre and post secondary classrooms, however, in reality, CS has become a fundamental component of many STEM disciplines – often known as big data. In order to develop a pipeline of K12 students with CS skills and competencies, the current K12 STEM teachers need to not only acquire those same CS skills but also the pedagogical skills and self-efficacy to teach their students. If a post secondary CS education requires four years of coursework, then how can we expect our K12 teachers to gain the required STEM subject matter expertise, CS competencies, and educational pedagogy while teaching? The study highlighted in this paper, focuses on the novel use of a freely available technology to develop teacher learners' fundamental CS knowledge and skills through active exploration (constructive approach). NetLogo is a multi-agent simulator that uses the educational Logo programming language and was designed for K12 classroom modeling experiences (Wilensky & Papert, 2010). The integration of a freely-available, existing technology (web or computer-based), NetLogo (Wilensky, 1999), prepared and developed the skills of K12 teachers to incorporate CS foundations with their own science activities. The authors strived to teach the teachers to think like CS engineers and engineering educators so that they could do the same with their K12 students.

2. Purpose, Problem, and Research Question
CS, as a part of engineering education, is at the forefront of education policy (Obama, 2016) and the media, but how the US builds a pipeline of teachers to teach the subject to our students is up for debate (Cannady, Greenwald, & Harris, 2014). The traditional pipeline of K12 STEM teachers relies on collegiate level STEM majors (and minors) who pursue teaching certification. In order to provide an adequate pipeline of teachers capable of teaching CS concepts, the current K12 teachers in the pipeline should have CS professional development (PD) opportunities. The PDs should address the challenge facing today's teachers in how to incorporate CS concepts into existing curriculum in order to 1) enhance existing instruction, 2) provide relevant examples and contextual grounding of CS in the real world, and 3) teach fundamental concepts of CS. These three challenges all require that teachers have two things: 1) sufficient CS content knowledge and 2) self-efficacy to incorporate concepts into the classroom. This study shows how K12 teachers use CS and NetLogo using during 3 days of a 16-day PD called RAMPED (which stands for Robotics, Applied Mathematics, Physics, and Engineering Design). Following Sengupta, Dickes, Farris, Karan, Martin, and Wright (2015), the authors of this paper ask, "How can K12 science teachers, who may have little or no programming experience, teach such classes?" The authors used PD, and consequently, the research question inquired:

How do K12 teachers view their skill set of using computer science in their classrooms before, during, and after PD?

3. Theoretical Framework and Literature Review
The authors embraced a social constructivism theoretical framework, where interactions between people (in this case K12 teachers) allow for the creation of connections and content understanding of the CS material presented (Vygotsky, 1978). The NetLogo session, presented in this paper, was based on group construction of NetLogo ideas, coding meanings and changes, and simulated modeling experiences. Teachers created K12 classroom ideas for CS and NetLogo, and the data shows these collaborations. Additionally, the authors utilized Pea and Collins' (2008) concept of the fourth wave of science education reform which,

…involves the emergence of a systemic approach to designing learning environments for advancing coherent understanding of science subject matter by learners. Science educators and researchers have recognized the need for planful coordination of
curriculum design, activities, and tools to support different teaching methods that can foster students’ expertise in linking and connecting disparate ideas concerning science, embedded learning assessments that can guide instructional practices, and teacher professional development supports that can foster continued learning about how to improve teaching practice.

Using technology (such as NetLogo) with K12 teachers, so that they can explore and create using CS concepts for classrooms, is an extension of prior research relating to four main areas including: 1) NetLogo and CS background; 2) K12 students using and learning CS; 3) K12 teachers using and learning CS; and 4) Higher education student and faculty using and learning CS. These four themes are highlighted in the following literature review.

Overall, previous research indicates "involvement with modeling scientific phenomena and complex systems can play a powerful role in science learning" (Hashem & Mioduser, 2011, p. 151). The four themes stated earlier relate to teaching teachers to think like engineers and are important for engineering educators at all levels to consider. There have been successes in advancing engineering education and CS through modeling, science standards, and more, however, there is room for improvement on motivating K12 teachers to use engineering and CS in classrooms (see the following section for details).

The first theme of engineering educations' CS technology focuses on background information about the descriptions of NetLogo as a multi-agent programming language and modeling environment (Blikstein, Abrahamson, & Wilensky, 2005; Tisue & Wilensky, 2004a; Tisue & Wilensky, 2004b; Wilensky, 2001; Wilensky, 1999). NetLogo is a multi-agent simulator that leverages the popular Logo programming language, which was originally developed as a ‘learning language.’ Multi-agent simulators define the characteristics and/or behaviors of a specific agent (e.g., ant, worker ant, queen ant, etc.). The simulator then allows an end user to create many copies of that agent in a predefined world (e.g., ant colony, a flock of birds, atoms, photons, etc.). Lastly, the simulator controls the interactions of the agents within the world according to the predefined (programmed) rules (e.g. ants following pheromone trails, birds flocking, atoms binding, the behavior of light, etc.) (Goel, Rugaber, & Vattam, 2009; Malan & Leitner, 2007).

Secondly, another major literature theme explores K12 student technology use with CS interactions (Basu, Dickes, Kinnebrew, Sengupta, & Biswas, 2013; Berland & Reiser, 2011; Sengupta, Dickes, Farris, Karan, Martin, & Wright, 2015; Sviha & Linn, 2012; Vattam, Goel, Rugaber, Hmelo-Silver, Jordan, Gray, & Sinha, 2011). Ultimately, there are a plethora of CS projects for researchers to explore with K12 teachers and students by using NetLogo (or other approaches that use Arduinos or Raspberry Pis which the K12 teachers explored in other aspects of the RAMPED PD). Although there are many options, K12 teachers still struggle to incorporate authentic science, engineering, and CS into classrooms (Burrows, 2015; Burrows, DiPompeo, Myers, Hickox, Borowczak, French, & Schwartz, 2016).

technologies to enhance educational opportunities and strengthen proven methods of learning” (p. 7). Researchers make arguments that "the cognitive and sociocultural factors related to learning complex systems knowledge are relevant and challenging areas for learning sciences research" (Jacobson & Wilensky, 2006, p. 11). Thus, teaching K12 teachers to utilize CS exploration is complicated and should be systemic.

Finally, CS is encouraged and needed in higher education as well (Blikstein, 2011; Blikstein, 2013; Blikstein & Wilensky, 2005; Blikstein & Wilensky, 2010; Chiu & Wu, 2009; Hashem & Mioduser, 2011; Klasnja-Milicevic, Vesin, Ivanovic, & Budimac, 2011; Levy & Wilensky, 2009; Maroulis, Guimera, Petry, Stringer, Gomez, Amaral, & Wilensky, Pathak, Kim, Jacobson, & Zhang, 2011; Sengupta 2010; & Wilensky, 2009; Shen, Lei, Chag, & Namdar, 2014; Wilensky & Papert, 2010). However, as Blikstein & Wilensky (2010) claim,

A common element in those [higher education] programs is to introduce courses in which students design products and solutions for real-world problems, engaging in actual engineering projects. These initiatives have met with some success and are proliferating into many engineering schools. Despite their success, they have not addressed one key issue in transforming engineering education: extending the pedagogical and motivational advantages of design-based courses to theory-based engineering courses, which constitute the majority of the coursework in a typical engineering degree, and in which traditional pedagogical approaches are still predominant (p. 17).

Hence, higher education instructor pedagogy and translation to K12 teachers is an area in need of additional study.

4. Methods
During a 16-day, yearlong engineering education PD focused on CS applications, experts conducted six independent sessions in two-day blocks. Twenty-two teachers (a subset of the 30 total STEM teachers), including beginning teachers from a Noyce program (called SWARMS), participated in the NetLogo sessions of RAMPED. This study, which gathered quantitative and qualitative components, asked how K12 teachers viewed the engineering component of CS before, during, and after the RAMPED PD. The eight members of the RAMPED team, which consisted of two education faculty, four STEM faculty, one STEM graduate student, and one industry professional, collected qualitative and quantitative data via formal assessment questions on surveys including: 1) perceptions of CS knowledge and self-efficacy and 2) open ended questions on classroom implementation plans. Informal interviews were conducted as well. Additionally, an independent evaluator collected both qualitative data on PD satisfaction and classroom implementation planning along with quantitative pre/post content competency data.

5. The Study, Participants, and Limitations
The data for this study was collected during a two-week engineering education PD for K12 STEM teachers to enhance their CS content knowledge and self-efficacy with the topic. Thirty teachers participated in the yearlong PD, but only 22 K12 teachers participated in the NetLogo sessions, and only 20 K12 teachers completed the pre/post survey data for this study. There was a close to even split between elementary, middle and high school teachers in the participant pool. However, all of the teachers taught science and mathematics (although five teachers also taught technology, art, and/or engineering). The PD focused on real-world applications of CS and the authors implemented a set of six, two-day sessions. The two-day sessions included: 1) NetLogo Naturally Inspired (NNI), 2) Space, 3) Robotics, 4) Virtual Reality, 5) Arduinos, and 6) Raspberry Pi. The K12 teachers chose four of the six total sessions to attend during the two summer weeks (10 days) and then attended all of the extension sessions on all six topics during the academic year (6 days). Due to logistics, each session was implemented twice in the summer and limited to 11 teachers during each offering. Primary instruction for each session was provided by content experts and supplemented by pedagogical sessions led by education faculty.
This study focused on both the engineering CS content knowledge as well as the perceptions of engineering CS self-efficacy and classroom implementation among 22 K12 teachers. The 20 K12 teachers that completed the data reporting fell into the following general classifications: 35% high school teachers, 63% science focused teachers, an average of 12.9 years teaching, with 125.5 students per year with about 12% of those students on individualized education plans.

The objective of the RAMPED PD was to better teachers’ instruction and content knowledge by introducing teachers to applications of CS. Thus, the formal assessment consisted of both application and fundamental CS theory questions. The study showcases a subset of the pre/post assessment questions related to the fundamental CS theory. Table 1 contains the questions along with the CS concept(s) they assess. It is important to note that question seven, regarding the illustration of sequential operation, only contained graphical illustrations while all the remaining questions were related to real code statements in one of three programming languages: C++, Python or Logo.

Table 1. Assessment questions and corresponding CS concept(s).

<table>
<thead>
<tr>
<th>Question</th>
<th>Session</th>
<th>Assessment Question (Summary)</th>
<th>CS Concept(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q5</td>
<td>Baseline</td>
<td>Which command could be used to query a robot's joint state?</td>
<td>Syntax</td>
</tr>
<tr>
<td>Q7</td>
<td>Baseline</td>
<td>Which of the following illustrates sequential operation?</td>
<td>Control Structures</td>
</tr>
<tr>
<td>Q14</td>
<td>Baseline</td>
<td>Print out the numbers 1-10</td>
<td>Variables</td>
</tr>
<tr>
<td>Q17a</td>
<td>NNI</td>
<td>Show 1000 rolls of a fair 21-sided die</td>
<td>Control Structures, Randomness</td>
</tr>
<tr>
<td>Q17b</td>
<td>NNI</td>
<td>Create a process to swap to two numbers</td>
<td>Syntax</td>
</tr>
<tr>
<td>Q17c</td>
<td>NNI</td>
<td>Take a number and add one to it</td>
<td>Variables</td>
</tr>
<tr>
<td>Q17d</td>
<td>NNI</td>
<td>Report if a number is even or odd</td>
<td>Control Structures, Boolean Logic</td>
</tr>
</tbody>
</table>

There were several times that data was gathered. The participants of the PD answered these seven question prior to the start of the summer session (pre-pre), prior to the individual 2-day session (pre), immediately following the 2-day session (post), immediately following the summer session (post-post), prior to the follow-up session (pre-follow), immediately after the follow-up session (post-follow) and once again at the conclusion of 120 contact hours (final). There are seven data sets that form the basis for short-term and long-term impact of the CS content knowledge gains among the K12 teachers.

Limitations of the study include that the current participant pool is limited to 22 participants (with only 20 data participants), all of whom self-selected participation in the two-week paid PD. The group of participants came largely from the same general STEM teaching population. The participant pool, while evenly split between elementary, middle and high school teachers came mostly from the same school district. Additionally, the PD lasted two summer weeks with six follow-up sessions during the school year (total of 120 hours), which while desirable for a PD, was short to teach novices a new technical content area. The STEM content focused almost exclusively on CS, and further studies are required to generalize these results to other disciplinary PDs. The implementation survey was administered three months after the PD; however, to measure long-term adoption rates the authors need to collect more data (and this is happening). Finally, six of the eight PD experts were accustomed to educational outreach, which may be atypical in other technically focused PDs.

6. Analysis & Findings
Qualitative:
The authors utilized informal interviews regarding NetLogo with the K12 teachers as well as open-ended questions on the survey for qualitative responses. The main theme showed that the
K12 teachers desired to, and began to use NetLogo in classroom implementation more than the other five sessions (which are not a focus of this study). The authors coded responses from the open-ended questions and summarized results in Table 2.

Additionally, three months after the summer PD opportunity, teachers were surveyed on their CS implementation plans – both planned (potential) and already executed (current). The K12 teachers shared where they planned or used the engineering and CS PD experiences (Table 2 activity model or highlights). Key themes identified from the survey included: cost, planned activity models, and implementation approach and are expanded in Table 2.

**Table 2. Synthesized aggregation of teaching implementation plan, the current and potential implementation rate, cost, actual implementations, and the PD model.**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Current (Potential) Implementation Rate</th>
<th>Cost (USD)</th>
<th>Activity Model or Highlights</th>
<th>PD Session Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>NetLogo</td>
<td>10%(45%)</td>
<td>Free</td>
<td>Inquiry, Family Science Night</td>
<td>Inquiry &amp; explanation</td>
</tr>
<tr>
<td>Arduino</td>
<td>5%(20%)</td>
<td>&lt; $50</td>
<td>Electricity Unit</td>
<td>Lecture &amp; inquiry</td>
</tr>
<tr>
<td>Raspberry Pi</td>
<td>5% (30%)</td>
<td>&lt; $50</td>
<td>Integrated Project; Afterschool Club</td>
<td>Lecture &amp; inquiry</td>
</tr>
<tr>
<td>Space</td>
<td>0% (10%)</td>
<td>Free</td>
<td>Unknown</td>
<td>Lecture &amp; inquiry</td>
</tr>
<tr>
<td>Virtual Reality</td>
<td>5% (25%)</td>
<td>&lt; $25 = Google Cardboard &gt; $100s = Interactive VR</td>
<td>Lecture &amp; Lab</td>
<td>Lecture &amp; inquiry</td>
</tr>
</tbody>
</table>

Example quotes from the K12 teacher interviews/open-ended questions (following this paragraph) were used for triangulation of the data:

- [I need] a little more on why a swap is so important in NetLogo or any programming language
- I love the idea of using NetLogo for modeling scenarios with students
- Love the program [NetLogo], my familiarity improved substantially through the workshop but also with the practice and working with [colleagues]
- [I will use the] applicable web-based opportunities
- My coding background is weak, so I had a hard time figuring out how to modify the code, including for the simulations. However, exposure to the simulations was excellent, so hopefully I can ID some of them and use them in class.
- [Doing this workshop has] re-establish[ed] the possibility of using one or more of the simulations models. A benefit would be initial student exposure to coding and using the library of simulations and manipulating the variables already coded.
- [I enjoyed] reviewing the web model and trying to change it.
- The hands-on pieces and the sequence cards were helpful in reading code in a clearer manner.

The authors saw themes of engineering CS participant engagement (e.g., "love;" "use them") as well as challenges (e.g., "a little more;" "hard time figuring out how") in the responses to NetLogo. Before the PD, the majority of the K12 teachers (90%) did not know about NetLogo and the CS applications. During and after the NetLogo session, the K12 teachers entertained the idea of incorporating engineering and CS concepts into their classes. The engagement is encouraging in light of the need for engineering and CS in K12 classrooms, and the challenges emphasize for continued study in this arena.
Quantitative:
The PD team created the content questions, used pre and post surveys, which are highlighted in Table 3 to showcase participant understanding of engineering and CS knowledge. Twenty PD participants responded to seven questions containing direct mappings to CS content knowledge on four separate occasions. The independent evaluator prepared pre and post survey questions to judge participant engagement and learning as well.

Table 3 summarizes the percentage of correct responses (questions are shown earlier in Table 1) among the participants for each of the four data collection points including: 1) before the entire PD (pre-pre), 2) immediately prior to a specific session (pre), 3) immediately following a specific session (post) and 4) at the end of the entire PD (post-post). Note that the general trend between the first three data points is strictly increasing and that the most fluctuation occurs between the post assessment and the final post-post assessment. This change is clearly visible in Figure 1 and summarized in Table 3.

Table 3. Percentage of correct CS content answers for PD participants.

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre-Pre</th>
<th>Pre</th>
<th>Post</th>
<th>Post-Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>6%</td>
<td>18%</td>
<td>44%</td>
<td>26%</td>
</tr>
<tr>
<td>7</td>
<td>39%</td>
<td>45%</td>
<td>90%</td>
<td>82%</td>
</tr>
<tr>
<td>14</td>
<td>32%</td>
<td>39%</td>
<td>55%</td>
<td>86%</td>
</tr>
<tr>
<td>17a</td>
<td>60%</td>
<td>60%</td>
<td>68%</td>
<td>100%</td>
</tr>
<tr>
<td>17b</td>
<td>29%</td>
<td>55%</td>
<td>59%</td>
<td>80%</td>
</tr>
<tr>
<td>17c</td>
<td>30%</td>
<td>35%</td>
<td>36%</td>
<td>50%</td>
</tr>
<tr>
<td>17d</td>
<td>48%</td>
<td>53%</td>
<td>70%</td>
<td>62%</td>
</tr>
</tbody>
</table>

Based on higher content knowledge scores and the corresponding higher self-efficacy scores that lead to K12 classroom use, as shown in the literature, the evidence in Table 3 provides support for the effectiveness of using NetLogo. It is a technology that can introduce K12 teachers and ultimately, through classroom implementations, the students to fundamental CS concepts through inquiry-based activities.

Although most teachers (90%) did not know about NetLogo, findings from the data (surveys and independent evaluator) show that the K12 teachers report high use expectations for their NetLogo skillset (but not necessarily CS) in their classroom teaching. Specifically, on a scale where 0 is not skillful at all and 5 is extremely skillful, NetLogo session survey pretest results show over 50% of participants at a 3, 4, or 5 level [5/22 at a 1 (23%), 6/22 at a 2 (27%), 7/22 at a 3 (32%), 2/22 at a 4 (10%), and 2/22 at a 5 (10%)]. Whereas, NetLogo session posttest survey results show over 90% of participants at a 3, 4, or 5 level [1/21 at 2 (5%), 6/21 at a 3 (29%), 9/21 at a 4 (43%), and 5/21 at a 5 (24%)]. After all of the summer sessions in the exit survey, 95% of K12 teachers stated that NetLogo was useful to them [1/20 to a small extent (5%), 6/20 moderate extent (30%), and 13/20 large extent (65%)].

After the academic year follow-up session (held on a Friday late afternoon and Saturday all day in October 2016), K12 teacher satisfaction with NetLogo was over 75% [1/22 completely dissatisfied (5%), 3/22 mostly dissatisfied (14%), 1/22 slightly dissatisfied (5%), 1/22 slightly satisfied (5%), 5/22 mostly satisfied (23%), and 11/22 completely satisfied (50%)]. Over 85% of teachers believed that the NetLogo workshop "stretched teacher thinking into their classrooms" [2/22 small extent (9%), 8/22 moderate extent (36%), and 12/22 large extent (55%)]. Overall, teachers enjoyed and planned to use engineering CS and NetLogo concepts in their K12 classrooms after the PD because their perceived level of CS and NetLogo expertise increased.
7. Conclusions and Implications

Engineering and CS are rapidly becoming a "must teach" subject for K12 teachers across all disciplines and grade levels. Unfortunately, many teachers lack the specific CS content knowledge, self-efficacy, and resources to effectively incorporate CS within their existing curriculum. This study shows that using a specific tool, such as NetLogo, tends to create comfort with the tool along with K12 teacher classroom use, but sustainability and complete CS integration is still far off for most of the K12 teachers even after the 16 day PD with 3-day NetLogo immersion. The participants' CS engagement is encouraging in light of the need for engineering and CS in K12 classrooms, and their challenges emphasize the need for K12 teacher sustained engineering and CS expert support. If the desire to use engineering and CS is present, but there are hurdles for K12 teachers to overcome, then engineering educators can assist in filling this gap.

Interestingly, but not the focus of this study, five of the six sessions were taught by faculty that used a traditional lecture followed by inquiry experiences, but the NetLogo session was taught by a faculty member that used a brief introduction and then allowed the K12 teachers to explore the possibilities of NetLogo modeling in their own exploratory way (and offered explanations along the way). Some have argued that the session approach made the difference in K12 teacher use of NetLogo, however, other sessions have shown through K12 lesson over the last six months. This paper focused on how K12 teachers viewed their skill set of using CS in their classrooms before, during, and after the RAMPED PD. Yet, based on the data and analysis presented in this paper, the authors believe that NetLogo (or any other similar) technology, when used in an exploratory, inquiry-based fashion, is capable of enabling teachers to incorporate CS into their K12 classrooms.

The authors argue that K12 teachers can learn basic CS fundamentals through exploration in a constructivist environment with a free, online programming technology (like NetLogo) and without structured, lecture-oriented sessions. Implications are widespread, as K12 teachers can potentially increase their own CS content knowledge and self-efficacy and this could influence CS implementation, which can lead to the incorporation of more CS into K12 daily activities and standard-based instruction. Finally, the authors believe that STEM teachers, in conjunction with CS content experts, should use NetLogo or a similar technology, as a tool within CS PD. Additionally, the authors would propose that K12 STEM teachers could self-engage or create a NetLogo Professional Learning Community (PLC) to augment these exploratory CS opportunities. Experience with CS and NetLogo does increase teacher content knowledge and
self-efficacy and does lead to K12 teacher created STEM lessons incorporating engineering, CS, and NetLogo. Teaching teachers to think like engineers is important, timely, and needed for K12 school classrooms, and using CS strategies is one means of moving them to do just that.

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