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# Four Strategies for Driving a University Pre-College Computing Outreach Program

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**ABSTRACT**

A public university's computing outreach program focused on four key strategies for increasing the depth and breadth of science, technology, engineering, and mathematics (STEM) education. This paper describes the development and implementation of a project management hands-on learning laboratory activity within the context of the university's outreach strategies. The first two strategies, establishing relationships with the primary and secondary (K–12) level partner schools and implementing whole-grade participation, have led to repeat visits by students over several years. The third strategy, hands-on learning laboratory activities, has successfully engaged K–12 students, as indicated by the assessment results that provide evidence of successful student learning. The fourth strategy, producer–consumer collaborations, has facilitated the efficient matching of faculty expertise with K–12 teacher needs. The results include the evidence that outreach strategies can have a positive influence on student engagement in STEM education at multiple points in the K–12 education experience.

**Keywords:** STEM, Computing education, IS education, Project management, Assessment

## 1. INTRODUCTION

Computers are increasingly ubiquitous, and employment opportunities in science, technology, engineering, and mathematics (STEM), and especially in computing, are expected to expand. The number of occupations in computer and information technology is projected to grow by 13 percent between 2016 and 2026. This is faster than the average for all other occupations. These occupations are projected to add approximately 527,169 new jobs (Kessler, 2017). The demand for workers will come from the increased emphasis on cloud computing, information security, and the collection and storage of big data. The median annual wage for computer and information technology occupations in the United States was $84,580 in May 2017. This was higher than the median annual wage of $37,690 for all other occupations (U.S. Bureau of Labor Statistics, 2018).

It would seem therefore that there would be an increase in computing program student enrollments and, consequently, the supply of computing labor in response to this job growth. Yet, according to the Bureau of Labor Statistics, in 2012, there were more than twice as many computing jobs as there were graduates (Withers, 2013). This shortage has continued. The U.S. Department of Labor estimated that 1.4 million computing-related jobs were available in 2010. However, based on the estimated rate of bachelor's degree graduates, the United States only had the ability to fill 30% of these jobs (National Center of Educational Statistics, 2009). Studies have shown that many students, especially women and minorities, lose interest in STEM as early as middle school (fifth or sixth through the eighth grades, or ages 10 through 13–14) and therefore do not even consider careers in computing when making college decisions (Morella, 2013).

Although interest in some STEM fields is growing, interest in computing has declined. High school student enrollment

(Grades 9 through 12, ages 14 through 17–18) in STEM classes has increased for all of the disciplines except computer science (CS), for which, according to the 2009 National Assessment of Educational Progress High School Transcript Study, enrollment has dropped from 25% to 19% from 1990 to 2010 (Nord et al., 2011). The data on women and underrepresented minority students are even more troubling. Women earn 18% of the undergraduate degrees in computer and information sciences, and minority students earn only 10.6% of all bachelor's degrees granted in the United States (National Center of Educational Statistics, 2009).

It is possible that a concentrated effort on computing education at the primary and secondary school levels, as was done with the other STEM disciplines, could produce similar results. In the United States, primary education includes kindergarten (ages 4–5) and Grades 1 (ages 5–6) through 8 (ages 13–14). Secondary education, otherwise known as high school, comprises Grades 9 (ages 14–15) through 12 (ages 17–18). Together, these formative years of education are known as K–12. During these pre-college years, exposure to computing has been shown to influence students' college major choices (College Board, 2011). In a 2010 survey of Google employees, 98% of the computing majors, as compared to 45% of the non-computing majors, reported having had exposure to computing prior to entering college (College Board, 2011). This exposure to computing ranged from attending after-school clubs, computing camps, and middle or high school classes to reading about CS. The computing majors were more likely to have reported knowing that computing was a viable career path while they were still in middle or high school (College Board, 2011). By 2015, the demand for computing jobs had reached 527,169; however, there were only 59,581 graduates (Kessler, 2017).

In an effort to address the shortages, many STEM education initiatives, such as code.org, Boosting Engineering Science and Technology (BEST) Robotics, Girls Excelling in Math and Science (GEMS), and the National Center for Women and Information Technology (NCWIT; Klawe, Whitney, and Simard, 2009), have been adopted in the United States. These initiatives have reported varying degrees of effectiveness in increasing the number of students enrolled in STEM majors. These initiatives have merit, and regional participation, particularly because it involves K–12 activities, is supported by this paper's authors. Delaying outreach until the junior or senior year may be too late; therefore, earlier K–12 interventions have promise for reaching students before they lose interest.

Drawbacks of K–12 initiatives, however, are that they often cater to the students who are already interested in computing or they rely on student self-selection. These approaches severely limit the potential of these initiatives to have broad effects and to significantly increase participation.

This paper describes a new approach to K–12 outreach: a more comprehensive strategy that does not rely on student self-selection. At the setting for this study, a technology college at a medium-size public university in the southern United States, the co-authors developed an educational outreach program around four key strategies:

- Partner schools
- Whole-grade participation
- Hands-on learning laboratories
- Producer–consumer collaboration

Each of these strategies has been critical to the success of the outreach program.

The remainder of this paper will discuss the four key strategies, describe the development of a specific hands-on learning laboratory activity (HOLLA) within the context of these strategies, and present some of the outcomes.

## 2. PRIMARY AND SECONDARY SCHOOL OUTREACH: A COMPREHENSIVE APPROACH

The impetus for educational outreach was motivated by the technology college's goal to increase the recruitment of undergraduate computing majors. Because of the aim of exposing high school juniors and seniors to the campus, the newly built computing facility, hereafter referred to as Tech Hall, was the chosen venue for this outreach program. Completed in 2012, Tech Hall is a state-of-the-art building that is home to several STEM programs, including a four-year ABET-accredited information systems (IS) degree program. The new impressive building, with its modern classrooms, laboratories, aesthetically impressive atrium, and popular coffee shop, provided an attractive venue. However, offering outreach programs to college-bound upperclassman proved difficult because of competition with other colleges vying for the attention and participation of the few computing-ready, math-capable juniors (11th graders) and seniors (12th graders). Thus, the outreach goal was redefined and decoupled from recruiting.

### 2.1 Outreach Strategy 1 of 4: Partner Schools

First, the key stakeholders, including the school administrators, industry partners, and industry professionals, were consulted. They were asked how the college could "add value" through its K–12 strategy. It was discovered that the K–12 schools had an interest in outreach to all grade levels. Rather than focusing on the high school juniors and seniors, the students who were of immediate interest, the college developed a comprehensive program beginning in kindergarten to cultivate an on-going relationship with students. In each case, the whole school was recruited, and an agreement was made to send students from multiple grades to the college. Access was provided to extensive educational offerings in computing, starting with the programming environment Scratch to appeal to kindergarteners (Lifelong Kindergarten Group, 2019). The goal was to create hands-on computing activities that were interesting to all students throughout the grades.

Through the partner school strategy, formally known as the Partner School Program, the outreach has had a long-term effect. Each school has agreed to visit Tech Hall at least twice, usually fall and spring, each year. This allows for up to 26 activities over the 13 years of a student's K–12 experience. In addition, some middle schools have been participating in one-week computing camps.

The literature suggests that multiple visits to a field trip venue can have a positive influence because students learn best when there is a balance between the novelty of the setting and the novelty of the material (Meiers, 2010). It is possible that on a first trip, regardless of the type of activity, the students might be focused on their surroundings and remember the visit as a trip to a new place. By repeatedly returning to the same venue, they will focus more on the learning material and computing than Tech Hall, thereby retaining more of the material.

### 2.2 Outreach Strategy 2 of 4: Whole-Grade Participation

Paired with the establishment of the Partner School Program is the second strategy: whole-grade participation. Student participation in the outreach program is by grade-level. Whole-grade participation is a method for facilitating a partner school's agreement to include all the students from a single grade level (e.g., fourth or fifth grade) on a visit. The goal was to introduce the computing outreach activities to as many students as possible rather than targeting specific students, who are often self-identified (or the parents of these students), or computing clubs. Agreements were reached with the K–12 partner schools that all the students would participate.

With whole-grade participation, all students attend the outreach activities regardless of self-selection or an interest in computing. Because everyone in the grade participates, the ability to increase the participation of female and minority students and to have an effect on a larger number of students is strengthened. Through the design of learning activities for the participation of an entire grade, the important goal of sparking an interest in students who have previously shown no interest in computing can be accomplished. As has been the case with field trips at other facilities (Marshdoyle, Bowman, and Mullins, 1982), an early positive experience could cultivate a lifelong interest.

### 2.3 Outreach Strategy 3 of 4: Hands-On Learning Laboratory Activities

The third outreach strategy involved the outreach activity itself with its goal of participatory learning rather than mere observation. This instructional component of the comprehensive outreach strategy is the HOLLA. HOLLAs are one-hour self-contained learning lessons designed to teach computing principles at the K–12 level. HOLLAs are similar to field trips in that the students travel from their schools to an offsite location, Tech Hall in this instance, for the purpose of learning. However, unlike many field trips, HOLLAs employ constructivism and active learning strategies by providing hands-on activities. Each HOLLA is designed with specific learning outcomes that relate to the K–12 educational curriculum. The students learn through participation in problem-solving activities rather than observation or listening to lectures. No preparation is required by the students for participation in the HOLLAs. This is an important feature because it accommodates the wide range of skill levels that are encountered in whole-grade participation. A key component of some of the HOLLAs is the incorporation of team-based learning (TBL) strategies (Michaelsen and Knight, 2004).

### 2.4 Outreach Strategy 4 of 4: Producer–Consumer Collaboration

The fourth outreach strategy defines the approach to delivering the complete set of HOLLAs for the K–12 partners. A review of the literature suggests that facilitating field visits, fostering positive working relationships with schools (Marshdoyle, Bowman, and Mullins, 1982), and reinforcing the curriculum (Melber, 2008) are important. Accordingly, each of the K–12 partner schools were viewed by us as a valuable stakeholder whose needs had to be met. However, the collaborations with multiple grade levels at several schools made it nearly impossible to customize the activities for specific K–12 teachers, classes, or grade levels.

The decision was made to focus on a more efficient form of collaboration: the producer–consumer model. This model has been used in organizations to promote software reuse (Joos, 1994) by focusing separately on the production and consumption processes, each of which has its own behavioral incentives. Considering computing HOLLAs as a product, the faculty members produced HOLLAs on the basis of their areas of expertise and interest. Every HOLLA developed by the faculty or acquired from the college's internal marketplace is available to the consumers, i.e., the teachers at the K–12 partner schools. As consumers, the K–12 teachers can choose any of the HOLLAs that are offered for whatever reason they see fit. They can match their instructional needs to the available HOLLAs. The producers produce the HOLLAs, and the consumers consume them independently as is typical with software reuse and business marketplaces.

## 3. CASE STUDY: THE PROJECT MANAGEMENT HANDS-ON LEARNING LABORATORY ACTIVITY

A case study was conducted to examine the development of a HOLLA focused on project management (PM) and its effects on K–12 STEM outreach strategies. Developing and producing a PM Critical Path HOLLA provided several benefits. This subject area gave the co-authors an opportunity to use their PM expertise and to expose the K–12 partners to topics in less well-known computing majors such as IS. The strategy was to package the components, including PM and collaborative problem-solving, that had not been well-represented in the other HOLLAs and to apply the TBL instructional strategies and assessments advocated by the college.

As one of the many HOLLAs created for the Partner School Program, this laboratory activity focused on the critical path method, a PM technique for planning and tracking project schedules. The concepts are taught in a PM course required in the IS degree program. The description of this HOLLA is as follows:

> *The students will be introduced to basic project management concepts such as the project triple constraints of scope, cost, and time. Students will learn about the critical path method, used by project managers to plan a project's schedule. Students will start with a project's activity network diagram and then learn how to calculate the expected time to complete a project and identify the critical paths for a project. This HOLLA will allow the students to experience the Team-Based Learning approach that is used in several courses throughout our university. This will allow the students to work as a group to perform an activity applying the concepts being taught within the HOLLA.*

Project scheduling is fundamental to PM in all fields. It is not limited to computing. A scheduling activity automatically integrates two key project areas: scope and time. It can also be easily extended to consider cost, quality, and human resource considerations. These are included in the HOLLA. The focus on the critical path method means that a generally accepted quantitative PM method is used. It challenges the students but is simple enough to be understood in the allotted time frame. In addition, it facilitates problem-solving with an objective, one-best-answer solution.

This HOLLA was designed in accordance with the principles of TBL (Michaelsen and Knight, 2004). One of these principles is the creation of collaborative activities. With TBL, an application activity is an assignment designed to foster higher-order thinking (Michaelsen and Knight 2004) in the important outcome areas. For these activities to be effective in a collaborative environment, they should be designed to create accountability and to foster discussion. For the design of TBL application activities, the four Ss (hereafter referred to as 4S) are recommended: significant problem, same problem, specific choice, and simultaneous reporting.

A significant problem will be easily understood by students, and it will capture their interest. They will be able to immediately apply the learned concepts to the problem. It was therefore necessary to design an activity that would be familiar to the learners in the various grade levels. In addition, no assumptions were to be made about the students' knowledge of computing. The problem presented for this HOLLA was making a bacon, lettuce, and tomato (BLT) sandwich. Students of all ages and grade levels could relate to making a sandwich. The activities and the steps involved did not need additional explanation. The students could immediately start to solve the problem by applying the critical path concepts being taught.

The same problem concept means that all teams work on the same problem. Thus, the teams were given the same "make a sandwich" problem. Because they all worked on the same problem, accountability was created across the teams. To solve the problem, each team would then be able to compare its solution to the other teams' and to reflect on the quality of their own solution. Such feedback is much more meaningful than if the teams had worked on separate problems or versions of the sandwich problem with different options.

A specific choice design presents better opportunities for higher-order thinking than does an activity such as a "make a list" problem because the teams are required to make a series of decisions that must be justified. In the case of making a sandwich, the teams had to prioritize the activities, decide what could be done simultaneously, identify the unique paths through the project network diagram, and decide on the path that allowed for completion within the estimated time. These activities presented opportunities for the students to develop the higher-order thinking skills that would enable them to be engaged in problem-solving.

Finally, it was necessary to ensure that the activity would provide simultaneous reporting. When all teams work on the same problem, there is the potential for answer drift. This means that while a student or team is reporting its results, the other teams would have the opportunity to alter their solutions. To prevent this, each team submitted its completed solution independent of the other teams' solutions.

After several drafts had been completed, the HOLLA consisted of a 20-minute lecture with interactive discussion, a team formation activity, a series of three team application activities, and a team quiz (see Table 1).

| Learning Activity Type | Topic | Allocated Time | Elapsed Time |
|---|---|---|---|
| Interactive lecture/discussion | What is a project? Why is this project important? | :20 | :20 |
| Individual exercise | Psychological survey | :05 | :25 |
| Individual activity | Find your psychological profile | :01 | :26 |
| Team balancing activity | Group students with mix of profiles | :03 | :29 |
| Team activity | Sequence the sandwich activities | :02 | :31 |
| Team question | How long does it take to make the sandwich? | :01 | :32 |
| Interactive discussion | How can you shorten the time? | :03 | :35 |
| Team activity | Create parallel paths | :05 | :40 |
| Team activity | Critical path analysis | :05 | :45 |
| Team quiz | Review PM critical path concepts | :10 | :55 |
| Presentation | Winning team & takeaways | :05 | :60 |

**Table 1. Breaking Down the Project Management Critical Path Hands-On Learning Laboratory Activity**

In the penultimate activity, the teams work on creating parallel path solutions to make their sandwiches efficiently. The correct solution is shown in Figure 1.

In the final activity, the students calculate the length of the critical path and, thus, the project completion time, which is 12 minutes.

## 4. RESULTS: OUTCOMES OF OUTREACH STRATEGIES

The K–12 outreach program has grown quickly since 2012 as a result of the strategies employed. Six faculty members produced 46 HOLLAs, 39 of which are currently available. More than half have been utilized. The most popular HOLLAs have been Scratch (programming), Alice (object-oriented programming), project management, brain-computer interface, Blender (coordinate math), video podcasting, Animation

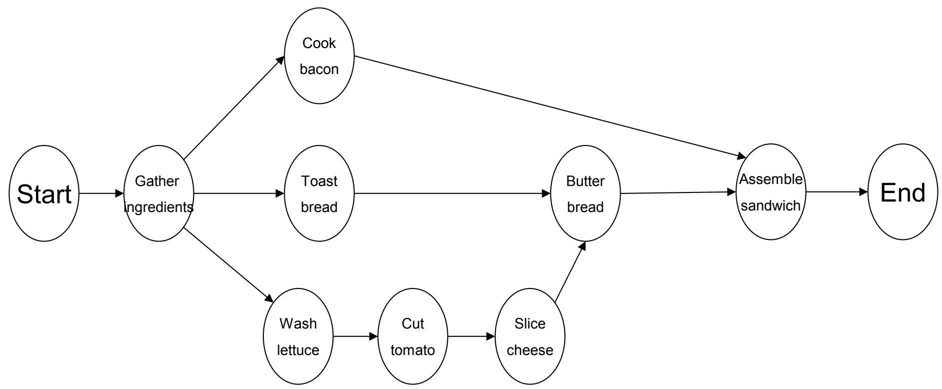


**Figure 1. "Make a Sandwich" Project Critical Path Solution**

Mania, retro gaming, turning on an LED light through a Raspberry Pi computer, cryptography, steganography, and ethical hacking.

The 2016–2017 academic year saw the highest participation levels thus far. A total of 4,456 students from the nine partner schools visited the campus for 13,620 person hours. Two-thirds of the visitors attended the HOLLAs and spent two hours on campus. Another 361 attended camps at which they spent approximately 20 hours. The typical two-hour HOLLA visit has 15–50 students accompanied by a teacher and two adult volunteers. When the group is larger than 20, they are split into two alternating groups, with the groups switching rooms as each alternate between the two one-hour HOLLAs.

The primary objective of this paper is to describe some of the outcomes of a comprehensive K–12 computing outreach program implemented through a PM Critical Path HOLLA. Thus, each of the four outreach strategies are presented with respect to its effects on the success of this HOLLA.

### 4.1 Outcomes of Strategy 1 of 4: Partner Schools

The partner school strategy allowed for significantly more students to be exposed to the concepts of PM and critical paths. It afforded an opportunity for the PM Critical Path HOLLA to be marketed across the relevant grade levels at all of the participants in the partner school program. A fifth-grade teacher was the first to select the HOLLA, and over time, Grades 5 and 8–12 from four schools followed. Without the partner school strategy, fewer schools and grade levels would likely have participated in this outreach program, and it is possible that there might have been no need for or interest in the PM topics covered. Most of the partner schools make two visits per year per grade. Thus, students in multiple grades have been introduced to the program. They have attended subsequent PM HOLLAs that have built on this original program.

The partner school strategy was highly successful. It is the cornerstone of the outreach program. Many local public and private schools have asked to be involved. Customizing the approach with the help of the stakeholders made it possible to attract the attention of the top high schools. One of the top math and science high schools in the state asked to participate. The average ACT score at this public school was 25.0 in 2016 (Niche, 2019). The state average was 19.1, and the national average was 20.8 (Broderick, 2016) Subsequently, a state-chartered math and science school also joined. Offering options for students in all grades allowed for the alignment with the schools' goal of producing more math-capable students.

### 4.2 Outcomes of Strategy 2 of 4: Whole-Grade Participation

The whole-grade participation strategy requires that all HOLLAs appeal to more than just the computer-savvy or self-selected students. Thus, the PM Critical Path HOLLA focused on non-computer concepts (projects, management, and teams) and examples outside computing (Olympic Games, home construction, and sandwich-making) to give the lessons a broader appeal. Without the implementation of the whole-grade participation strategy, the PM Critical Path HOLLA could have included more technical or computing-intensive content to meet the higher skill levels of the computer-savvy students. However, the inclusivity of the program resulted in the exposure of entire grade levels of K–12 students and their teachers to some of the course content in the college's IS, information technology, and health informatics programs. Most of the K–12 partners had a general idea of CS; however, they were not aware of the many disciplines, such as IS, within computing. The PM Critical Path HOLLA therefore succeeded in creating awareness about the other computing disciplines.

### 4.3 Outcomes of Strategy 3 of 4: Hands-On Learning Laboratory Activities

The HOLLA strategy, with its focus on hands-on learning activities, appealed to the designers who used TBL strategies and assessments in their own courses. The designs for the PM Critical Path HOLLA contain team activities with specific and assessable solutions. The TBL 4S design allows teams to compete to be the first to find the correct solution to the same problem. Without the HOLLA strategy, the outreach event might have taken the form of a simple lecture or presentation. It may not have even been developed because of the lack of a demonstrable project to target the visitors who may have had preferences for observational and entertainment experiences. The PM Critical Path HOLLA enabled the students to develop a broader view of computing.

The students learned about management: the importance of people and teams and the use of techniques such as critical path analysis for solving technical management problems. It is possible that the opportunity to develop this broader view would encourage the students to decide to enter a STEM field. Our internal reporting suggests that the HOLLA was effective at both engaging the students and fostering learning. The following sections present the observations for each of the engagement and learning effects.

**4.3.1 Evidence of engagement.** Over the repeated offerings of the PM Critical Path HOLLA, at least four different measures of student engagement have been applied. First, the students answered interactive questions readily and insightfully. Second, having paid attention to the instructions, the students immediately and successfully engaged in team activities. Third, the students, sometimes with the help of their teachers, recognized the applicability of PM to their school activities. Fourth, they participated so enthusiastically in the final activity, the team quiz, they continued to work when time was up.

During the interactive-discussion, the most interesting interaction to note in regard to our first point is when students were asked “How can you shorten the time?” This is asked immediately after the teams have completed the sequencing activity in which they lay sandwich activity cards end to end in logical order and calculate the time, which is up to 21 minutes. The instructor would then remark: “That’s a long time to make a sandwich. If you took that long to make your lunch, you might miss the school bus. How can you shorten the time?” Invariably, the students will offer suggestions such as those provided in Table 2. The instructor’s replies are useful for reinforcing the key concepts and, more importantly, rewarding the students for their insights. Of course, the answers are not always the same; however, on most occasions, several of the same broad answers are provided. They illustrate attention to, interest in, and insights about the task.

The second point, immediate participation in the activities, has been the norm. The teams almost always get right to the task. If the students need guidance, the instructor or an assistant can help them to get them started. Most teams complete all the activities without a great deal of assistance.

The third point emphasizes the significance to the learner. As was previously mentioned, this is a key aspect of the TBL 4S activities and the justification for the choice of the sandwich problem. The students also recognize that PM applies to everyday school life, such as term papers, science fairs, and the homecoming dance. These types of topics have almost always been mentioned in the interactive discussions.

Regarding the fourth point, participation in the quiz, the student teams have been highly motivated to complete the quiz even when they were not being scored. Often, there has not been enough time, and the session ends prematurely. Students do not want to stop and conclude the activity when the end of the instructional content is reached. Rather than being clock-watchers, they are engaged to the end. They usually want to finish the quiz.

**4.3.2 Evidence of learning.** Learning occurs through the activities. To assess learning, student performance is measured through the team quiz and, where possible, the individual version of the quiz. The PM Critical Path HOLLA has been offered many times to students at various levels. The results are provided below. The performance on the team and individual quizzes has provided evidence of student learning. For students taking the quiz by guessing or providing randomly selected answers, the expected score is 25%, as each answer has four possible choices. The scores have been much higher than would have been possible from guessing, thus indicating the likelihood of student learning. Appendix A provides a full list of the assessment items.

The results from the recent HOLLAs are summarized in Table 3. All of the HOLLAs contained the PM Critical Path content and six-item team quiz. The grade levels in this sample ranged from 8 through 12. Three different types of school groups are represented: a large public school’s STEM academy, a private school’s entire grade, and a statewide magnet boarding school’s entire grade. For purposes of anonymity, the schools are listed as Schools 1, 2, and 3. The mean of the team quiz for the individual HOLLAs ranged from 81 to 97, with a grand mean of 86. In two cases, an individual quiz and the team quiz were given. The means, 74% and 71%, respectively, were significantly higher than what could be achieved through guessing. These results support the conclusion that the students and teams took the HOLLAs seriously, and learning occurred.

| Student Suggestion | Instructor’s Reply |
|---|---|
| Remove the cheese | Good idea. Does cheese belong on a BLT? Not really. Principle: Remove unnecessary tasks from the project. |
| Remove the bacon | This would save 8 minutes: more time than removing any other task. But it’s the main ingredient: something the customer would want more than anything. You had better ask the customer, “Would you eat an LT sandwich?” Come to think of it, you should ask them about the cheese, too. |
| Bacon only | That would save 13 minutes and take 8 minutes total to make. Cook the bacon, and out you go. That’s a good barebones lunch. Sometimes, the barebones project is all the customer can afford or is willing to risk his money on. |
| Get mom to help | This is adding a human resource. Most projects are executed in teams. |
| Prewash the lettuce and buy pre-sliced cheese | We call this outsourcing. |
| Microwave the bacon | You can cut the time in half, but will the bacon taste the same? It’s a quality–time tradeoff: part of the triple vs. quadruple constraint. |
| Lightly toast the bread | While the first three ideas reduce the tasks (scope) to save time, the last four keep the tasks but reduce time in other ways. |
| While the bacon is cooking, you can be washing the lettuce | That’s called doing things in parallel, and that is what we are going to learn about next. |

**Table 2. Student Engagement: Sample Interactions**

| | Grade Level | No. of Teams | Team Means | Individual Means (where applicable) |
|---|---|---|---|---|
| School 1 | 8 | 18 | 81% | n/a |
| School 2 | 9 | 10 | 84% | n/a |
| School 3 | 9–10 | 3 | 86% | n/a |
| School 2 | 10 | 4 | 94% | 74% (n = 15) |
| School 2 | 11 | 5 | 97% | n/a |
| School 3 | 10–12 | 5 | 88% | 71% (n = 20) |

**Table 3. Summary of Recent Project Management Hands-On Learning Laboratory Activity Assessment**

**4.4 Outcomes of Strategy 4 of 4: Producer–Consumer Collaboration.**

The producer–consumer strategy was found to be effective, regarding both production and consumption. Faculty members were offered $200 by the college dean for every HOLLA developed and accepted for implementation by the outreach program director. This cash incentive resulted in three faculty members' producing 20 HOLLAs. Subsequently, 26 more HOLLAs were delivered outside the incentive program: 6 from a government-funded grant to deliver a computing camp and 19 developed gratis by faculty members. The cash incentive proved to be an effective stimulus for the production of the HOLLAs. It motivated a few faculty members to produce many of these programs. Unexpectedly, the momentum led to the production of more programs without the provision of additional incentives.

Consumption also worked in unexpected ways. The faculty member who designed the PM Critical Path HOLLA expected it to be selected by the teachers of secondary school juniors. It was thought that the students needed to be more mature to benefit from the inclusion of teamwork and management concepts. However, a teacher at a partner school reported that her school was introducing teamwork in the fifth-grade curriculum. Initially, the students often struggle, working in isolation rather than immediately collaborating or delineating the team activities. Thus, the PM activities that were incorporated into the HOLLA were appealing to the teacher, and she brought her fifth-grade class to Tech Hall.

The producer–consumer strategy enabled the designers to apply their areas of expertise and interest to the production of the HOLLAs without the need to focus on consumption. The result was the design of a HOLLA in which PM, teamwork, and assessment were valued and featured. Without the producer–consumer strategy, all of the HOLLAs would have had to be developed around the requirements of a specific teacher, grade level, or K–12 computing curriculum. It is therefore possible that the program would not have been as successful or as widely adopted.

## 5. EVIDENCE OF EFFECTS ON SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS EDUCATION

Beyond the reported outcomes for each of the strategies, the evidence suggests a cumulative effect for the K–12 program. This section reports on the current findings regarding the effects of the PM Critical Path HOLLA on STEM education.

In addition to being educational and engaging, the PM Critical Path HOLLA led to more visits. After experiencing the HOLLA with her fifth-grade class, the teacher returned with eighth graders who completed not only the PM Critical Path HOLLA but also its "sequel," the Project Scheduling HOLLA, during a week-long camp. In the Project Scheduling HOLLA, the students build early and late start schedules for the BLT sandwich activity and compute the slack. The partner school strategy makes it possible and relatively easy for a teacher to bring a second class of a different grade level.

In an interview, the fifth-grade teacher reiterated that the motivation for choosing the PM Critical Path HOLLA was to get the students to think about solving unstructured problems in teams. Up to the fourth grade, most students have relied on their parents' help for large or unstructured projects. In several of the middle school classes, the students are assigned to teams. For example, in American History, the students work creatively together to learn about the Civil War. They write a song parody. In the Young Scientist Challenge, the students choose a topic and write a plan. Interestingly, despite being the class most closely aligned with computing, mathematics had few group projects. It is likely that in showing the relationships to courses other than mathematics, the PM Critical Path HOLLA had a positive influence on attitudes to STEM by revealing connections to the wider world.

This teacher reported that overall, she believed that the involvement with the university through the HOLLAs, which start in the lower grades, has definitely influenced the attitudes about STEM. Her school had very little computing in its pre-five curriculum. After the second-grade students began the HOLLA visits during which learning was facilitated through Scratch the Cat, she noticed that the students in the fourth to sixth grades started to choose more technically demanding projects for their technical fairs. For example, many students would make a PowerPoint presentation to meet the basic requirements. After their participation in the program, they were more likely to complete a more technical hands-on project, such as programming.

In 2018, she also organized STEM Days, a two-day event for sixth graders. The students can make some choices regarding the types of challenges they want to complete. She found that more students were selecting computer-based rather than engineering projects. The projects included engineering a tower that could withstand hurricane-force winds that were simulated by a large powerful fan. Many students chose software engineering projects. They used the easily programmable micro-bit computer and Microsoft MakeCode software to complete projects such as building a door bell for the hearing impaired or designing safer street crossings.

Together, the partner school and whole-grade participation strategies have increased the number of student interactions across the K–12 experience, thereby increasing the potential benefits of such STEM activities. Since the program began in 2012, some of the students who have experienced the most extensive outreach through the partner schools have graduated. One such school is a large local public school participated in the PM Critical Path HOLLA and a computing camp. This school reported that 12 of its seniors had planned to enroll at the

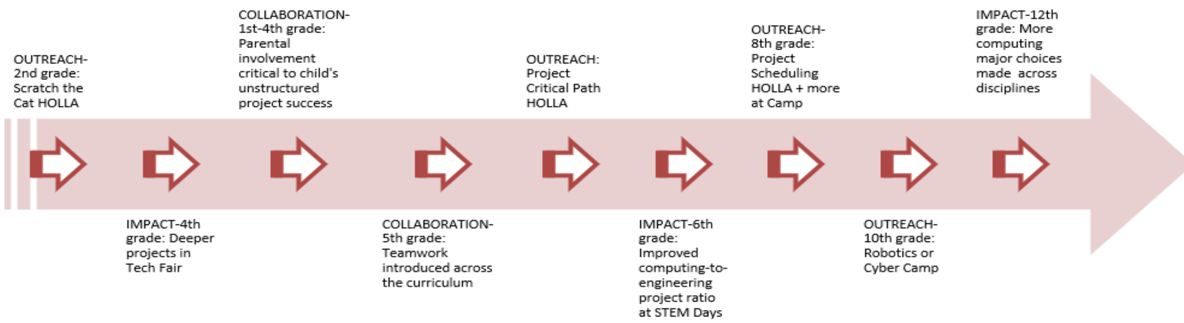


**Figure 2. Timeline of Effects of Science, Technology, Engineering, and Mathematics Education**

university in Fall 2018 to major in one of the computing degree programs. This is a considerable increase from the four or five students who have typically come from that school.

Figure 2 illustrates the effects of the K–12 outreach on STEM engagement and learning. It should be noted that the timeline presents a composite of two partner schools and that not all occurrences of outreach are shown. The graphic was designed to illustrate the ongoing effects of this comprehensive outreach strategy. An early second-grade effect followed by repeat visits (not shown) resulted in a fourth-grade effect. Additional outreach was made to the fifth grade, and the positive effects of STEM were observed in the sixth through eighth grades. The outreach also influenced college choices.

## 6. CONCLUSIONS

The outreach strategy examined in this case study challenged conventional wisdom by engaging not only the students who had an interest in computers but also those who did not. The participants included students in grades lower than those that are typically of interest to colleges. The evidence suggests that this strategy, with its emphasis on K–12 partner schools, whole-grade participation, producer–consumer delivery, and hands-on learning, was successful. The development of a team-based HOLLA on PM and its selection by the middle and high school teachers at multiple partner schools has been examined in this paper. Influenced by the outreach strategies, the design of the HOLLA resulted in the creation of an engaging set of activities that broadened the students' views on computing. The results of the assessment are an indication of the serious approach of engaged individuals to the hands-on activities as well as evidence of student learning.

Moreover, the depth and breadth of the K–12 strategy demonstrates the positive influence of this comprehensive approach on engagement in and attitudes towards STEM. An interview with a middle school teacher indicated that the effects were evident at multiple points in the K–12 experience. A second partner school that has also had students participating at multiple points during their educational process has seen a twofold increase in the number of graduates who choose computing majors at the university under study.

### 6.1 Lessons Learned

While the strategies employed in this program yielded favorable outcomes, there have been operational challenges. In the beginning of the program, the legal issue of minors on the university campus had to be addressed. The three main issues were insurance coverage (public school insurance policies often require the college to be named as an additional insured), personal identifying information (the college does not collect data on the K–12 students), and adult supervision (the schools supply one adult for every 10 students).

While the implementation of the producer model demonstrated that faculty members could supply effective HOLLAs, their ability to deliver the HOLLAs each time they were needed was too much to expect. The faculty members were therefore asked to deliver the new HOLLAs for the first implementation only. Thereafter, part-time graduate assistants were able to view video recordings of the HOLLAs to learn to deliver them independently. The materials (presentation slides, lesson plans, learning objectives, and videos) for each HOLLA are accessible via a university web page.

Maintaining relationships with nine partner schools has been challenging; thus, some flexibility is needed. Schools have arrived late, canceled sessions, or changed the number of students who were expected to attend. A change in the number of students has consequences that include team sizes and the availability of seating and materials. The worst example of a cancellation occurred in 2018 when a major weather event, a rare ice storm in the South, caused some schools to be closed for several days. So as not to lose additional in-class days, the schools cancelled their HOLLA appointments. Although the preference is for all the HOLLAs to be held in Tech Hall, they have sometimes been conducted offsite at the request of the partner schools.

Despite the coordination issues, the program is run effectively by a part-time staff member and a system administrator whose time is shared with other programs. A list of available HOLLAs is published online, along with a calendar that shows the scheduled HOLLAs and the slots available to the partner schools upon request. Some schools make additional outreach requests, such as guest speakers for classes or assemblies and assistance with their computing curricula. Of course, every effort is made to support these requests. However, the cooperation of the faculty is also needed. Being a good partner is critical to achieving the benefits of the outreach program.

### 6.2 Future Work

Additional work is needed. All of the effects of the outreach and HOLLA strategies are still to be examined. The partner schools have not all graduated a class of seniors yet who have fully experienced the outreach strategies. The data have not been systematically collected throughout the life of the program; thus, the establishment of causes and effects may be difficult. In addition, the influence of the broader view of computing offered by the PM Critical Path HOLLA on student attitudes is yet to be investigated. The effects of future visits should be studied. The students' and teachers' post-HOLLA reflections on the effects of their experiences on their approaches to the K–12 curriculum should be studied. Finally, the influence on student career choices should be examined.

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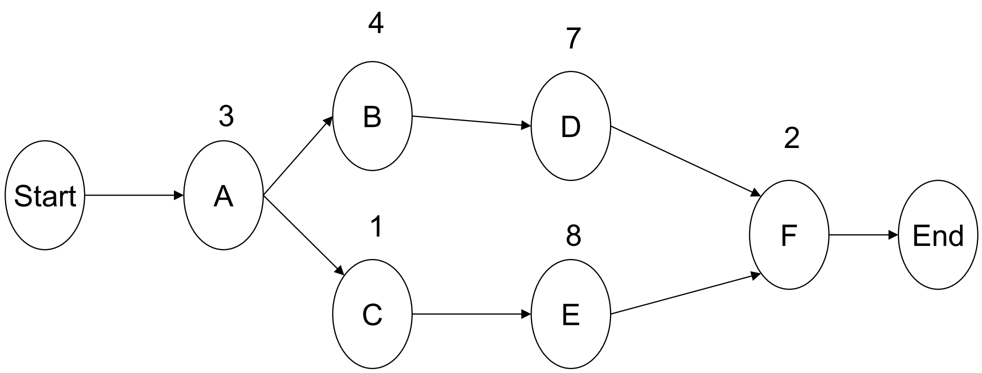
**Appendix A**

**Assessment Quiz**

**Multiple Choice** (Note: You should choose the best answer among the four alternatives.)

*A-Mail the invitations, B-Print the invitations, C-Cater the party, D-Create the guest list, E-Finalize the food order, F-Wait for the RSVPs*

1. Which activity sequence is logically correct in terms of task dependencies for a birthday party? (See above.)
   a. D–B–A–F–E–C
   b. D–B–E–A–F–C
   c. B–D–A–E–C–F
   d. A–B–C–D–E–F




*Use the project network diagram above with duration estimates (in weeks) listed above each activity to complete items 2–5 below.*

2. How many paths are there through the network diagram?
   a. 2 c. 4
   b. 3 d. 1

3. What is the critical path?
   a. A–B–D–E–F c. A–B–C–D–E–F
   b. A–C–E–F d. A–B–D–F

4. What is the total project duration (in weeks)?
   a. 30 weeks c. 16 weeks
   b. 14 weeks d. 25 weeks

5. Assuming we start the project at Week 0, what is the earliest that activity F can start?
   a. Week 14 c. Week 16
   b. Week 23 d. Week 12

6. For a wedding project, which of the following activities can be performed in parallel with “wait for alterations to the dress”?
   a. Try on dresses
   b. Take photographs
   c. Cut the cake
   d. Mail the invitations

Key: 1-a, 2-a, 3-d, 4-c, 5-a, 6-d

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