The Golden LEAF STEM Initiative Evaluation

Final Report

Malinda Faber, Sherry Booth, Brandy Parker, Danny Stanhope, and Jeni Corn, The Friday Institute for Educational Innovation

Nicole Ross and Doug Lauen, Carolina Institute for Public Policy

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The Golden LEAF Foundation
301 N. Winstead Avenue
Rocky Mount, NC 27804
(252) 442-7474
www.goldenleaf.org
# Golden LEAF STEM Initiative

June 2015

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The Final Evaluation Report in a Series

This Final Report summarizes the total findings from Year One through Year Three of the Golden LEAF STEM Initiative. The report also provides some overall reflections and recommendations based on the findings. Annual formative evaluation reports, including a baseline report (Corn, 2012), a year one report (Corn, 2012), and year two report (Faber, 2013), can be found at cerenc.org.

1. Introduction

The Golden LEAF STEM Initiative

In 2010 the Golden LEAF Foundation (Golden LEAF), based in Rocky Mount, North Carolina, launched a public school “STEM Initiative.” It focused on preparing 4th- through 9th-grade students in North Carolina’s rural, economically distressed, and/or tobacco-dependent counties for careers requiring science, technology, engineering, and math (STEM) competencies. A special program of the Golden LEAF Board of Directors, the STEM Initiative targeted projects that:

- Targeted improved performance in STEM subjects by racial/ethnic minorities, females, and students from limited-resource families;
- Implemented curricula that integrated content, used project- and inquiry-based instructional strategies, and/or prepared students for completion of Algebra 1 by 8th or 9th grade;
- Provided content-specific professional development for teachers;
- Were evidence-based approaches to STEM education incorporating in-school, out-of-school, and extended-day programs;
- Represented collaborations among public schools and institutes of higher education, community partners, and/or industry partners; and/or
- Provided career and work connections for teachers and students.¹

In the spring of 2011 fourteen grants were funded for a three-year period. The smallest grant was $100,000 to support a single-school and the largest was $600,000 to aid a regional collaboration.

¹ For more information see www.goldenleaf.org.
The overarching goals of the STEM Initiative were to enhance teachers’ instructional practices, increase student attitudes, and increase student learning in STEM. More specifically regarding instructional practices, the initiative aimed to support an increase in participating teachers’ use of inquiry-based instructional strategies, creation of content-integration, and application of rigorous content-knowledge. Regarding student attitudes, which educational psychologists generally consider to be comprised of sub-concepts like student motivation, self-efficacy, positive learning values, and interest, the initiative was particularly interested in increasing student motivation and self-efficacy. Finally, to support student learning in STEM, the initiative was most interested not only in increased achievement on standardized tests, but also increased engagement and increased acquisition of skills critical to long-term success in STEM fields such as critical-thinking, problem-solving, and collaboration. While still debated among researchers, “engagement” generally refers to some combination of behavioral engagement (e.g. levels participation), emotional engagement (e.g. positive or negative emotional reactions), and/or cognitive engagement (e.g. levels of investment in learning). When students are engaged they are involved in the classroom activities, they persist despite challenges, and they take delight in the outcomes. Researchers have found that, over time, increased student attitudes and engagement have been associated with increased student learning outcomes (Fredericks, Blumenfeld, & Paris, 2004; Marks, 2000).

To these ends every grant’s main strategies included professional development for teachers, supporting them to use these materials effectively and implement inquiry-based and/or problem-based instruction. Every grant program also provided students opportunities for engaged, hands-on learning in STEM subjects, such as:

- Lab materials to test acceleration or model physiological processes;
- Digital probes to collect data on changing temperatures in liquids;
- Electrical sensors and other materials for building and programming robots;
- Curricular materials for leading students through engineering design challenges;
- Manipulatives and high-quality curricula to teach problem-based math; and
- Field trips to local STEM industry facilities.
In summary, eight common strategies were implemented. Each of the grants implemented two or more of these while also implementing unique program activities.

Table 1

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Grants Implementing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science kits (Discovery Science, CIBL, SEPUP)</td>
<td>3</td>
</tr>
<tr>
<td>Professional learning communities</td>
<td>3</td>
</tr>
<tr>
<td>Project Lead the Way</td>
<td>6</td>
</tr>
<tr>
<td>Science professional development</td>
<td>9</td>
</tr>
<tr>
<td>Math professional development</td>
<td>7</td>
</tr>
<tr>
<td>Integration of technology tools for STEM education</td>
<td>6</td>
</tr>
<tr>
<td>After-school and/or summer enrichment programs</td>
<td>6</td>
</tr>
<tr>
<td>Business partnerships</td>
<td>5</td>
</tr>
<tr>
<td>Higher education partnerships</td>
<td>7</td>
</tr>
</tbody>
</table>

The Initiative affected 43 school districts and thousands of students from spring 2011 through spring 2014. Of participating schools 84.0% were elementary or middle schools, which is a higher representation than is found broadly across North Carolina. For more detailed information about the Golden LEAF STEM Initiative grants, see Appendix A.

Figure 2. Total Students and Teachers Affected by the STEM Initiative, 2011-14

~ 31,890 students
~ 1,190 teachers
225 schools
43 school districts

2 All North Carolina Public Schools, including schools participating in the Golden LEAF STEM Initiative: Elementary PK-8 = 72.8% (N=1,828); Secondary Grades 9-12 = 16.6% (N=417); and Combined = 4.0% (N=100). The North Carolina Department of Instruction does not distinguish between traditional Elementary (Grades PK-5) and traditional Middle (Grades 6-8) schools in their public release of Facts and Figure data. Source: North Carolina Department of Instruction Facts and Figures 2011-2012 Report http://www.ncpublicschools.org/docs/fbs/resources/data/factsfigures/2011-12figures.pdf
Golden LEAF STEM Initiative
June 2015

Table 2
STEM Initiative Schools in Year One by School-Level

<table>
<thead>
<tr>
<th>School-Level</th>
<th>Number</th>
<th>Proportion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elementary</td>
<td>107</td>
<td>48%</td>
</tr>
<tr>
<td>Middle</td>
<td>82</td>
<td>36%</td>
</tr>
<tr>
<td>High</td>
<td>17</td>
<td>8%</td>
</tr>
<tr>
<td>Combined</td>
<td>10</td>
<td>4%</td>
</tr>
</tbody>
</table>

*Note: “Elementary” includes grades 4-5; “Middle” includes grades 6-8; “High” includes grades 9-12, 9-13, and Early Colleges; and “Combined” includes grades K-8, 5-6. Remaining schools were classified as “other.”*

**Evaluation Design, Data Sources, and Analysis Methods**

Golden LEAF charged the Evaluation Team at North Carolina State University’s William and Ida Friday Institute for Educational Innovation (The Friday Institute) with evaluating the collective impacts of these 14 grants over the three-year implementation period. The SERVE Center at the University of North Carolina at Greensboro supported the work in Years One and Two and the Carolina Institute for Public Policy at the University of North Carolina at Chapel Hill supported the work primarily in Years One and Three. Additionally, Golden LEAF charged the team with conducting evaluation capacity-building activities with the grant coordinators throughout the initiative.

*Figure 3. STEM Initiative Timeline*

The Evaluation Team, along with other researchers at North Carolina State University, developed a model for how changes in student educational experiences lead to changes in student learning and participation in the STEM pipeline through high school graduation. This model was used to guide the development of the evaluation plan.
**Evaluation Objective 1: Describe the Overall Effectiveness of the Initiative**

The evaluation of the Golden LEAF STEM Initiative was designed as a cluster, outcome evaluation – individual grants were not evaluated. The study focused on understanding the commonalities of the 14 grants’ activities and investigating common outcomes.

The change model (Figure 4) guided the development of three primary evaluation questions:

“In what ways is the STEM Initiative effective in changing:

1. Teachers’ instructional practices in STEM?
2. Student attitudes toward STEM?
3. Student learning in STEM?”

The evaluation applied a mixed-methods approach to answer the three questions, leveraging the benefits of both quantitative and qualitative methodologies (Creswell, 2009; Johnson & Onwuegbuzie, 2004; Raudenbush, 2005). This approach has particular advantages for studies exploring science and mathematics education and teacher quality programs (Day, Sammons, & Gu, 2008; Lawrenz & Huffman, 2006). Qualitative data will be analyzed using a grounded theory approach, extracting themes or “codes” from the text and grouping them into categories. Quantitative data collected will be analyzed for descriptive results and comparisons of subgroups.
Over the course of the study the evaluation team developed multiple instruments for measuring outcomes, including:

- **Surveys**: student, teacher, and principal;
- **Interview and focus group protocols**: grant coordinator, teacher, and student; and
- **STEM program implementation rubrics**: elementary, middle, and high school.

More detailed descriptions of the data sources and analysis methods can be found in Appendix B.

**Table 3**

*The Golden LEAF STEM Initiative Evaluation Plan*

<table>
<thead>
<tr>
<th>In what ways is the STEM Initiative effective in changing …</th>
<th>Data Sources &amp; Administration Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students' attitudes toward STEM?</td>
<td>x*  x  x  x*  x</td>
</tr>
<tr>
<td>Teachers' instructional practices in STEM?</td>
<td>x  x  x  x  x</td>
</tr>
<tr>
<td>Student learning in STEM?</td>
<td>x  x  x  x</td>
</tr>
<tr>
<td>Important school-level contextual factors</td>
<td>x</td>
</tr>
</tbody>
</table>

**Year One (School Year 2011-12)**

**Teachers’ instructional practices in STEM?**

**Year Two (School Year 2012-13)**

**Teachers’ instructional practices in STEM?**

**Year Three (School Year 2013-14)**

**Teachers’ instructional practices in STEM?**

† North Carolina Education Research Data Center

* Pilot instrument developed by The Friday Institute
Evaluation Objective 2: Development of Evaluation Capacity among Grantees

Golden LEAF also charged the evaluation team with providing program-evaluation technical assistance to the grantees as they worked to improve their programs. The evaluation team assisted each of the grant coordinator(s) to:

1. Develop foundational knowledge of program evaluation in education; and
2. Collect, interpret, and use formative data to improve their STEM education programs.

Throughout the initiative The Friday Institute led various evaluation capacity-building activities for the grant coordinators. Since this is the final evaluation report, the final June 2013 Summer Institute agenda and materials can be found in Appendix C.

Table 4
Golden LEAF STEM Initiative Evaluation Capacity-Building Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>When</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer Institute</td>
<td>Single-day, face-to-face workshops dedicated to: (1) developing and applying program evaluation knowledge to grant management, measurement, and reporting; and (2) sharing implementation successes and challenges</td>
<td>July 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>July 2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June 2013</td>
</tr>
<tr>
<td>Webinar</td>
<td>Hour-long synchronous webinars dedicated to: (1) developing and applying program evaluation knowledge to grant management, measurement, and reporting; and (2) sharing implementation successes and challenges</td>
<td>September 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>April 2012</td>
</tr>
<tr>
<td>Survey Results Reports</td>
<td>Individualized reports of a grant’s survey results; completed for both the student and teacher surveys</td>
<td>April 2012</td>
</tr>
<tr>
<td></td>
<td></td>
<td>April 2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>February 2014</td>
</tr>
<tr>
<td>Administrative Data Reports</td>
<td>Individualized reports comparing administrative data from the schools participating in each grant to all other schools in North Carolina</td>
<td>July 2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td>December 2013</td>
</tr>
<tr>
<td>Individualized Technical Assistance</td>
<td>Any of a variety of activities including face-to-face meetings, conference calls, emails, extra reports and data analysis templates, and additional survey administrations</td>
<td>Ongoing</td>
</tr>
</tbody>
</table>
II. Schools, Teachers, and Students Served by the Golden LEAF STEM Initiative

Characteristics of Schools Served

Findings from Administrative Data Analyses

The findings below illustrate broad characteristics of the schools participating in Golden LEAF STEM Initiative grants and their schools’ student and teacher populations. The findings were obtained by collecting and analyzing administrative data from the 2009-10, 2010-11, 2011-12, 2012-13, and 2013-14 school years.\(^3\) Data tables and full explanations of the results below can be found in Appendix D.

It is important to note that these results do not represent actual evaluation findings. These are characteristics of the entire student and teacher populations at each initiative school, not characteristics of the subsets of students and teachers who actually participated in initiative activities.

- Compared to other schools in North Carolina, higher proportions of students in schools in the STEM Initiative were from rural, White/Caucasian, and low-income families.\(^4\)

- Compared to other schools in North Carolina, 2013-14 student proficiency rates of students in STEM Initiative schools were slightly higher (1-2%) on mathematics standardized tests.

- Compared to other schools in North Carolina, 2013-14 student proficiency rates of students in STEM Initiative schools were slightly higher (1-2%) on science standardized tests.

- Compared to other students in North Carolina, in 2013-14 students in STEM Initiative schools were less proficient in 5th-grade mathematics. Of these students in STEM Initiative schools, females, Asians, and White/Caucasians were most proficient in mathematics.

- Female, Asian, and White/Caucasian students in both STEM Initiative schools and other schools in North Carolina had the highest proficiency rates in 5th- and 8th- grade mathematics in 2013-14.

- Students in the Free or Reduced Price Lunch program in STEM Initiative schools had higher proficiency rates in 5th- and 8th- grade mathematics than FRL students in other North Carolina schools in 2013-14.

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\(^3\) Data were collected from the North Carolina Education and Research Data Center. More recent data were not available as of the writing of this report.

\(^4\) This is expected because the Golden LEAF Foundation targets low-income, formerly tobacco-dependent regions of the state.
Male, Asian, and White/Caucasian students in both STEM Initiative schools and other schools in North Carolina had the highest proficiency rates in 5th- and 8th-grade science in 2013-14.

Female students and Asian students in both STEM Initiative schools and other schools in North Carolina had the highest proficiency rates in Algebra 1 in 2013-14.

Students in the Free or Reduced Price Lunch program in STEM Initiative schools had higher proficiency rates in Algebra 1 than FRL students in other North Carolina schools in 2013-14.

Asian and White/Caucasian students in both STEM Initiative schools and other schools in North Carolina had the highest proficiency rates in 9th and 10th grade biology in 2013-14.

Students in STEM Initiative schools took Algebra 1 at a pace similar to students in other North Carolina schools in 2013-14.

Students in STEM Initiative schools took Biology at a pace slower than students in other North Carolina schools in 2013-14.

Greater proportions of students in STEM Initiative schools took advanced/honors mathematics courses in 11th and 12th grades compared to students in other North Carolina schools in 2013-14.

Female students and Asian students in both STEM Initiative middle and high schools and other middle and high schools in North Carolina were much more likely than others to take advanced mathematics and science courses in 2013-14.

STEM Initiative schools met a lower proportion of accountability targets than other North Carolina schools in 2013-14.

Findings from the Golden LEAF STEM Implementation Rubric

In Years Two and Three principals of schools participating in the Golden LEAF STEM Initiative completed the online Golden LEAF STEM Implementation Rubric, reflecting on the level of implementation of STEM education broadly at their school. (In Year One a pilot version of the rubric was completed by the grant coordinator(s) for each of the 14 grants.)

Table 5

<table>
<thead>
<tr>
<th>Golden LEAF STEM Implementation Rubric</th>
<th>Year Two</th>
<th>Year Three</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Responses</td>
<td>Schools Impacted 2012-13</td>
</tr>
<tr>
<td>Elementary/Middle</td>
<td>76</td>
<td>230</td>
</tr>
<tr>
<td>High School</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>96</td>
<td>230</td>
</tr>
</tbody>
</table>
Comparisons between STEM Implementation Rubric results for Years Two and Three suggested that the greatest empirical gains (0.3 points on a four-point scale of “early” – 1, “developing” – 2, “prepared” – 3, and “model” – 4) were in the following attributes of STEM education:

- **Professional Development:** “Professional development on integrated STEM curriculum, community/industry partnerships and connections with postsecondary education” increased from 1.6 in Year Two to 1.9 in Year Three for high schools; and
- **STEM Education Plan:** “A communicated STEM plan is adopted across education, communities and businesses” increased from 1.3 in Year Two to 2.0 in Year Three for high schools.

The greatest setbacks were in the following areas:

- **Assessments and Exhibition:** “Authentic assessments and exhibition of STEM skills” decreased from 2.2 in Year Two to 1.9 in Year Three for elementary and middle schools.

Complete results from the administration of the STEM Implementation Rubric can be found in Appendix N.

**Characteristics of Students Served**

The evaluation team did not have access to unique identifying information of students who participated in activities supported by the Golden LEAF STEM Initiative grants. In Years One, Two, and Three grant coordinators administered the online Student Attitudes toward STEM (S-STEM) Survey to all students participating in the grants, thus allowing anonymous demographic and other self-reported data about the students to be collected.  

Every year the initiative-wide administration of the S-STEM Survey garnered high numbers of student responses (82%, 70%, and 85% respectively). The majority of those student respondents were middle school students (72%); this was expected since middle school students were the largest school-level sub-group of students participating in initiative activities. The majority of the students in Year Three self-identified as White/Caucasian (64%), 13% self-identified as Hispanic/Latino, and 11% self-identified as Black/African American.

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5 A pilot version of the Student Attitudes toward STEM (S-STEM) Survey was administered in Year One.
Table 6
*S-STEM Survey Response Rates by Year*

<table>
<thead>
<tr>
<th>S-STEM Survey Respondents</th>
<th>Y1</th>
<th>Y2</th>
<th>Y3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Elementary School (4-5th)</td>
<td>890</td>
<td>1,547</td>
<td>2,424</td>
</tr>
<tr>
<td>Middle and High School (6-12th)</td>
<td>8,779</td>
<td>10,195</td>
<td>9,234</td>
</tr>
<tr>
<td>Middle School</td>
<td>7,856</td>
<td>6,212</td>
<td>8,438</td>
</tr>
<tr>
<td>High School</td>
<td>923</td>
<td>3,981</td>
<td>796</td>
</tr>
<tr>
<td>Total</td>
<td>9,669</td>
<td>11,742</td>
<td>11,658</td>
</tr>
<tr>
<td>Estimated Student Participants</td>
<td>12,800</td>
<td>16,933</td>
<td>13,785</td>
</tr>
<tr>
<td>Estimated Response Rate</td>
<td>76%</td>
<td>69%</td>
<td>85%</td>
</tr>
</tbody>
</table>

*Note:* “Estimated Students Participants” and “Estimated Response Rate” were calculated based upon actual and estimated participant counts provided by grant coordinators. Counts shown represent totals after dropping results from students who did not answer at least 10 percent of survey questions.

Figure 5. S-STEM Survey Respondents by Race/Ethnicity

![Pie chart showing race/ethnicity distribution.]

Table 7
*Upper Elementary, Middle, and High School Student Demographic Characteristics in Year Three*

<table>
<thead>
<tr>
<th>Demographic Characteristic</th>
<th>Upper Elementary</th>
<th>Middle</th>
<th>High</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Elementary</td>
<td>2,424</td>
<td>8,436</td>
<td>795</td>
<td>11,655</td>
</tr>
<tr>
<td>Male</td>
<td>50.5%</td>
<td>51%</td>
<td>55%</td>
<td>51%</td>
</tr>
<tr>
<td>Female</td>
<td>49.5%</td>
<td>49%</td>
<td>45%</td>
<td>49%</td>
</tr>
</tbody>
</table>
9) Hispanic/Latino students were least likely to know adults who worked in a STEM career

In Year Two and Year Three when asked on the S-STEM Survey whether or not they knew any adults who worked as scientists, engineers, mathematicians, or technologists, students who self-identified as Hispanic/Latino were consistently least likely to report that they knew adults in STEM careers (Table 8; Faber et al., 2013). Findings were mixed in Year One (Corn, 2012). While research is not conclusive, some studies have begun to look for a link between students’ exposure to adults working in specific careers and the students’ academic performance in subjects related to those careers (Guiso et al., 2008; Reigle-Crumb & Moore, 2013).

Table 8
Student Awareness of Adults with STEM Careers by Race/Ethnicity in Year Three

<table>
<thead>
<tr>
<th>Yes, I know an adult who works as a/an …</th>
<th>Percentage of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>American Indian/AK Native</td>
</tr>
<tr>
<td>n</td>
<td>332</td>
</tr>
<tr>
<td>Scientist</td>
<td>29%</td>
</tr>
<tr>
<td>Engineer</td>
<td>65%</td>
</tr>
<tr>
<td>Mathematician</td>
<td>40%</td>
</tr>
<tr>
<td>Technologist</td>
<td>45%</td>
</tr>
</tbody>
</table>

Note: N values represent the number of students who answered all four questions.

10) Majority of middle and high school students planned to attend a four-year college, and females were more likely to plan to attend a four-year college than males

In Years Two and Three the S-STEM Survey asked middle and high school students whether they planned to attend college. The proportion of students who indicated “yes” increased slightly from Year Two (87%) to Year Three (89%). When compared by gender, females were more likely to indicate “yes” than males (93% and 85% respectively in Year Three). This trend was consistent in Year Two as well (91% and 82%).

Table 9
Middle and High School Student Plans to Attend College by Gender in Years Two and Three

<table>
<thead>
<tr>
<th>Do you plan to go to college?</th>
<th>Y2</th>
<th>All Students</th>
<th>Y3</th>
<th>All Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
<td>All Students</td>
<td>Female</td>
</tr>
<tr>
<td>n</td>
<td>3,913</td>
<td>4,014</td>
<td>7,934</td>
<td>4,254</td>
</tr>
<tr>
<td>Yes</td>
<td>91%</td>
<td>82%</td>
<td>87%</td>
<td>93%</td>
</tr>
<tr>
<td>No</td>
<td>0%*</td>
<td>3%</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>Not Sure</td>
<td>8%</td>
<td>15%</td>
<td>11%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Note: The 0% values marked with an asterisk are actually between 0% and 1%.
Those who agreed that they planned to attend college were then asked whether they planned to attend a two-year or a four-year college/university first. Averaged across Year Two and Year Three, approximately 77% of middle schools students and 76% of high school students indicated that they planned to attend a four-year college first.

### Table 10

**Plans to Attend First Either a Community College or Four-Year College/University by Grade-Level in Years Two and Three**

<table>
<thead>
<tr>
<th>Postsecondary Institution</th>
<th>Y2</th>
<th></th>
<th>Y3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Middle</td>
<td>High</td>
<td>Middle</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community College</td>
<td>5,670</td>
<td>986</td>
<td>7,077</td>
<td>678</td>
</tr>
<tr>
<td>Four-Year College/ University</td>
<td>78%</td>
<td>74%</td>
<td>76%</td>
<td>78%</td>
</tr>
</tbody>
</table>

### Characteristics of Teachers Served

The evaluation team did not have access to unique identifying information for teachers who participated in activities supported by the Golden LEAF STEM Initiative grants. In Years One, Two, and Three grant coordinators administered the online Teacher Efficacy and Attitudes toward STEM (T-STEM) Survey to all teachers participating in their grant, thus allowing anonymous demographic and other self-reported data about the teachers to be collected.6

In Years One and Two the T-STEM Survey was completed by an estimated 92% (Year One) and 96% (Year Two) of participating teachers. In Year Three the response rate was lower at 64%. The evaluation team identified no clear cause for this decline except for potential respondent fatigue. Across all three years elementary teachers (grades K-5) and science teachers (this included only middle and high school instructors) comprised the largest sub-groups of teachers by instructional area.

### Table 11

**T-STEM Survey Response Rates by Instructional Area and Year**

<table>
<thead>
<tr>
<th>T-STEM Survey</th>
<th>Y1</th>
<th>Y2</th>
<th>Y3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>222</td>
<td>149</td>
<td>98</td>
</tr>
<tr>
<td>Technology</td>
<td>54</td>
<td>42</td>
<td>54</td>
</tr>
<tr>
<td>Engineering</td>
<td>13</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Math</td>
<td>118</td>
<td>98</td>
<td>25</td>
</tr>
<tr>
<td>Elementary</td>
<td>236</td>
<td>246</td>
<td>92</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>643</td>
<td>544</td>
<td>284</td>
</tr>
<tr>
<td>Estimated Teacher Participants</td>
<td>700</td>
<td>565</td>
<td>444</td>
</tr>
<tr>
<td>Estimated Response Rate</td>
<td>92%</td>
<td>96%</td>
<td>64%</td>
</tr>
</tbody>
</table>

---

6 A pilot version of the Teacher Efficacy and Attitudes toward STEM (T-STEM) Survey was administered in Year One.
11) Majority of teachers were female and White/Caucasian

The majority of teachers who responded to the survey were female (79%). This proportion is consistent with the ratio of female to male teachers in the broader population of educators in North Carolina two years earlier (79% in 2011-12)\textsuperscript{7}. The largest ratio of female to male teachers was among the elementary educators and the smallest was among the engineering teachers. The majority of teachers who responded to the survey were White/Caucasian (89%), which is higher than the proportion in the broader population of educators in North Carolina (81% in 2011-12)\textsuperscript{8}.

*Figure 6. T-STEM Survey Respondents by Gender in Year Three*

*Table 12
T-STEM Survey Respondents by Race/Ethnicity and Instructional Area*

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Science</th>
<th>Technology</th>
<th>Engineering</th>
<th>Math</th>
<th>Elementary</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Indian/Alaska Native</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Asian</td>
<td>1%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%*</td>
</tr>
<tr>
<td>Black/African American</td>
<td>3%</td>
<td>11%</td>
<td>7%</td>
<td>12%</td>
<td>10%</td>
<td>8%</td>
</tr>
<tr>
<td>Native Hawaiian/Other</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Pacific Islander</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White/Caucasian</td>
<td>94%</td>
<td>85%</td>
<td>87%</td>
<td>84%</td>
<td>88%</td>
<td>89%</td>
</tr>
<tr>
<td>Hispanic/Latino</td>
<td>3%</td>
<td>2%</td>
<td>0%</td>
<td>4%</td>
<td>1%</td>
<td>2%</td>
</tr>
<tr>
<td>Multiracial</td>
<td>0%</td>
<td>0%</td>
<td>7%</td>
<td>0%</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Other</td>
<td>0%</td>
<td>2%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%*</td>
</tr>
</tbody>
</table>

Note. The 0% values marked with an asterisk are actually between 0% and 1%.

\textsuperscript{7} Figure from Carolina Institute for Public Policy’s 2011-12 administrative data-set.
\textsuperscript{8} Figure from Carolina Institute for Public Policy’s 2011-12 administrative data-set.
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12) Engineering teachers had the least experience

When compared by years of experience, engineering teachers had the least amount of experience (27% had “11 or more” years of experience teaching).

Table 13
*T-STEM Survey Respondent Years of Experience by Instructional Area*

<table>
<thead>
<tr>
<th>Total years of teaching experience</th>
<th>Science</th>
<th>Technology</th>
<th>Engineering</th>
<th>Math</th>
<th>Elementary</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>76</td>
<td>54</td>
<td>15</td>
<td>25</td>
<td>91</td>
<td>261</td>
</tr>
<tr>
<td>0 - 3 years</td>
<td>7%</td>
<td>19%</td>
<td>27%</td>
<td>8%</td>
<td>29%</td>
<td>18%</td>
</tr>
<tr>
<td>4 - 10 years</td>
<td>33%</td>
<td>20%</td>
<td>47%</td>
<td>40%</td>
<td>24%</td>
<td>29%</td>
</tr>
<tr>
<td>11 or more years</td>
<td>61%</td>
<td>61%</td>
<td>27%</td>
<td>52%</td>
<td>47%</td>
<td>53%</td>
</tr>
</tbody>
</table>

*Note.* Survey respondents provided their exact total years of teaching experience. Data were grouped into these three categories.

13) Approximately 16% of teachers had National Board Certification, lower than state average

Of those teachers who responded to the T-STEM Survey, 16% had National Board Certification, which is lower than the approximately 21% statewide. Compared by subject-area, math teachers had the highest proportion of National Board Certified teachers (28%), while engineering teachers again had the least (0%).

Table 14
*National Board Certification of T-STEM Survey Participants by Instructional Area*

<table>
<thead>
<tr>
<th>Are you National Board Certified?</th>
<th>Science</th>
<th>Technology</th>
<th>Engineering</th>
<th>Math</th>
<th>Elementary</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>76</td>
<td>54</td>
<td>15</td>
<td>25</td>
<td>92</td>
<td>262</td>
</tr>
<tr>
<td>Yes</td>
<td>17%</td>
<td>24%</td>
<td>0%</td>
<td>28%</td>
<td>11%</td>
<td>16%</td>
</tr>
<tr>
<td>No</td>
<td>83%</td>
<td>76%</td>
<td>100%</td>
<td>72%</td>
<td>89%</td>
<td>84%</td>
</tr>
</tbody>
</table>

III. Changes in Teachers’ Instructional Practices in STEM

The Golden LEAF STEM Initiative aimed to support teachers by funding activities that would facilitate increases in:

- Content integration;
- Project- and inquiry-based instruction;

9 See http://www.ncpublicschools.org/newsroom/news/2013-14/20131217-01
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Math instruction leading to students’ successful completion of Algebra 1 by eighth or ninth grade;

Content-specific professional development for teachers; and/or

Industry-connections for teachers.

To that end the 14 funded grants implemented new curricular materials, technological tools, and/or STEM-specific professional development. These activities included, but were not limited to:

- **Purchasing classroom materials and training**: For conducting experiments or designing solutions in the classroom, for example Lab Aids’ “SEPUP” kits and training or “Engineering is Elementary” kits and training;

- **Attending STEM education planning workshops**: Namely, taking teacher leaders and district staff to the Smithsonian Science Education Center’s LASER Institute, a week-long STEM education planning and instruction workshop in Washington, DC;

- **Creating teacher collaboration time**: More specifically, special opportunities for teachers in STEM subjects to gather and collaboratively develop projects; or

- **Funding teachers to attend professional conferences**: Related to STEM teaching and learning.

The T-STEM Survey was administered to teachers in Years One, Two, and Three and asked teachers to report about their confidence in teaching, the frequency with which they use various instructional strategies, and their knowledge about STEM careers. Individual focus groups were conducted with teachers from each grant in Years One, Two, and Three to complement the survey findings and gather detailed descriptions of any changes in teachers’ instructional practice. Phone interviews were conducted with grant coordinators each year for the same purpose.

Synthesized findings from the surveys, focus groups, and interviews are summarized below and suggest that grant activities:

- Enabled teachers to: increase their use of hands-on, inquiry-based instruction; increase their awareness of contemporary STEM careers; and integrate content from multiple subject areas.

- Provided beneficial professional development; and

- Were associated with a slight increase in self-efficacy (or confidence) in science and mathematics teachers.

**Grant Activities and Materials Enabled Teachers to Change Their Instructional Practice**

1) Initiative activities increased teachers’ use of inquiry-based, student-centered teaching strategies

Each year, when asked whether or not the grant activities had had an effect on teachers’ instructional practices, the strongest finding from both grant coordinator interviews and teacher focus groups suggested that the materials and training had increased teachers’ use of inquiry-
based, student-centered strategies. In many teacher focus groups in Year One and in the large majority of grant coordinator interviews and teacher focus groups in Years Two and Three, respondents stated that teachers were giving students more opportunities to ask questions and struggle with problems. This inquiry-based approach is an important instructional strategy for high-quality STEM learning.

*It’s changed my mindset. When I start a lesson now I don’t usually start it with, “This is what you are going to do.” I start it with a question instead of an answer and then their job is to find the answer ... So the labs affect how you teach other kinds of things too.*

(Grant Coordinator, Year Two)

The teachers are making intentional efforts to use more inquiry-based teaching. *I think that the projects have helped us out with that, and the kits by their nature have helped.*

(Teacher, Year One)

I’m just more open. For example, this year I’ve allowed the kids to create their own experiment. I would have never done that before my grant’s training. So I’ve become more open in those inquiry-based values.

(Teacher, Year Two)

The teachers aren’t just standing in the front of the room delivering instruction anymore. … They realize that you have to just let go of that control and let the kids do the math. And that’s been a huge shift for them, to let go of that.

(Grant Coordinator, Year Three)

I was very much leading with my questions, because I wanted them to get the content ... But sometimes I just needed to step back, to let them make a mess of it, and work their way through it. That was when it became concrete to them.

(Teacher, Year Three)

An indirect finding of the evaluation was that the inquiry-based activities aligned well with the state-level changes in educational standards taking place simultaneously. In 2011-12 North Carolina changed its mathematics and English/language arts educational standards to the multi-state developed, nationally-benchmarked Common Core State Standards (Common Core). While grant coordinators and teachers remarked throughout the three years that the transition to the Common Core had appropriated much of the current focus of schools and teachers, they also remarked that the Initiative activities and Common Core aligned well.

*Before the Common Core came in, it was very structured learning and what we were looking for is whether or not they got the answer. Now we’ve backed up, which is really good, and the process is more important than the answer. We’re asking them to backwards problem-solve, which is the most difficult problem-solving that there is for anybody.*

(Teacher, Year Three)

*I think [the science kits] can get [the problem-solving] process started with kids. Same thing with the integration of Common Core curriculum, the whole idea that you kind of have to teach kids how to do some of this problem-solving.*

(Teacher, Year Three)

*When Common Core came in last year, I think it caught a lot of the students off guard because of the rigor ... Obviously the Common Core has so many problem solving*
strands that are directly linked to our central standards in science ... [in a few years] I think we will really see it kind of take-off. (Teacher, Year Three)

2) Initiative materials helped some teachers integrate content, especially in Years Two and Three; teachers want more integrated materials and more time to collaborate

The Years Two and Three focus group protocols asked participating teachers how, if at all, the new STEM activities had affected the frequency and/or quality of content integration in their instruction. The findings were mixed. A number of teachers explained that the materials and training helped them integrate content from multiple disciplines.

It has put me in the mindset of using a lot more content integration, actually in all of my other science classes ... I think just having been through the grant program has put me more in that mindset, so I look for those opportunities where I may not have looked for them before ... it’s been a big boost for me and the kids that I teach. (Teacher, Year Two)

For me, I think [the most beneficial component of the grant activities] is the literacy component of the kits that tie everything together. And the math and science; how the students see that work together. (Teacher, Year Three)

At the same time, a number of teachers expressed their views that STEM subjects and other subjects were still being taught in isolation too frequently. The teachers suggested that more curriculum materials facilitating integration and more time to collaborate with colleagues would help increase integration.

I’m a math a teacher; I’m not a science person. As far as knowing the science curriculum and some of the stuff that they do, I still don’t know it ... If I could open up a book or something that said, “The science teacher is teaching this and is going to use this math skill,” it would be a snap. I need that document that takes all of my math skills and integrates it into the science curriculum. (Teacher, Year Two)

3) Majority of teachers reported implementing each of a variety of STEM instructional strategies in a little more than half of all instructional meetings

In Years Two and Three the T-STEM Survey asked teachers to indicate the average frequency with which they implemented a variety of instructional strategies common to STEM subjects. It is not possible for all activities to be implemented during every instructional meeting, and the results suggest that the majority of teachers implement each of the strategies in a little more than half of all their instructional meetings. From Year Two to Year Three teachers reported implementing the same three STEM instructional activities most frequently. The activities and proportions of teachers using these strategies “usually” or “every time” were:

- “Students work in small groups” – 64% (Year Two) and 66% (Year Three)
- “Students engage in content-driven dialogue” – 62% and 61%
- “Students complete activities in a real-world context” – 54% and 52%
From Year Two to Year Three teachers reported implementing the same three STEM instructional activities least frequently as well. The activities and proportions of teachers using these strategies “usually” or “every time” were:

- “Students learn about careers related to instructional content” – 48% (Year Two) and 36% (Year Three)
- “Students critique the reasoning of others” – 40% and 38%
- “Students reason abstractly” – 34% and 36%

Figure 7. Teacher Use of STEM Instructional Strategies in Year Three

During class how often do your students...
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June 2015

4) Visits to regional STEM industries greatly increased teachers’ awareness of contemporary applications of STEM content and STEM careers

Several Golden LEAF STEM Initiative grants used their funds to provide participating teachers with unique opportunities to visit local STEM industry facilities and meet STEM industry professionals. Results from three teacher focus groups in Year One, four in Year Two, three in Year Three, and multiple grant coordinator interviews in Years Two and Three suggested that these experiences provided teachers with critical awareness and information about contemporary applications of STEM concepts. In Year Three many grant coordinators reflected that connections with STEM industry partners were one of the top two successes of their grant.

*What was most beneficial to me was seeing what people go into if they go to two-year colleges after they get out of school. We went and looked at how car manufacturers use the technology and saw the same at a satellite dish company. We saw different things that students could use their skills for to find jobs after a two-year degree. It gave us a different outlook from what we normally see as teachers.* (Teacher, Year One)

*For me the visit was a very important, because we actually talk about bio-engineering in 8th grade science. The tour allowed me to see why it’s important to learn about bioengineering, what’s out there in the students’ future, the different kinds of jobs that are available for bioengineering, and why the whole idea of STEM is very, very important.* (Teacher, Year Two)

*Bringing in that community network - from a community college to the business community members - there’s a value-added piece there. That has really broadened our teachers’ understanding of where their knowledge applies beyond the classroom. I think that if you’re going to talk about STEM and its relevance to the world, you can’t do that just within your four walls; you’ve really got to engage with the community around you. And so I think that demonstrates how powerful those relationships have been.* (Grant Coordinator, Year Three)

Results from the T-STEM Survey indicated that teachers’ knowledge of careers in STEM fields increased from Year Two to Year Three as well. This was true especially among high school and elementary school teachers, which averaged 17 and 11 percentage point gains respectively across the four survey items.
Figure 8. Teacher Awareness of STEM Careers and Resources by School Level in Years Two and Three

Note: Responses were recorded on a five-point Likert scale: “strongly disagree” (1), “disagree” (2), “neither agree nor disagree” (3), “agree” (4), and “strongly agree” (5).

5) Teachers reported that the materials and resources were the most beneficial part of initiative; teachers and grant coordinators stated that more resources for STEM education are needed when asked to reflect on the most beneficial aspects of the grant activities, the majority of teachers responded that in resource poor schools simply having new materials and resources to implement hands-on, inquiry-based instruction was most beneficial.

Definitely the pieces for the investigations [were the most beneficial], because without those kits I would not have any science related materials, besides the old, outdated textbook that aren’t even written for my grade-level. (Teacher, Year Three)

I think [the kits] are a great direction to go. I think they’ve really made a difference and made the kids enjoy it. I enjoy teaching it and I can’t imagine having to go back and teach it a different way, or if something happened and we didn’t have the money to replenish the kits … I’d be lost. (Teacher, Year Three)
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At the same time most of the teachers and grant coordinators realized that this one-time grant support would not be enough to sustain this type of education. Grant coordinators described difficulty finding enough funding for bus transportation to take students to visit industries. Others explained that they lacked funding for important human resources, like staff who can provide technical support for digital learning tools or a STEM instructional coach for enhancing and improving instruction. The teachers suggested that more resources need to be found to enable high-quality STEM learning.

We’re trying to teach our students in a 21st century way with 19th century technology. And it’s not just the computers ... I’d love for them to have 3D modeling software to design their product right here and build it right here in the same spot ... It’s not engineering if you can’t apply it. (Teacher, Year One)

My primary issue is having a variety of materials for the kids to work with. Right now I average spending about $200 a month in materials out of my pocket for opportunities for the kids to do things better than what we have here ... If you don’t have the materials, it’s all theoretical again. (Teacher, Year One)

I think that STEM is awesome – I think that it’s not funded. (Teacher, Year Three)

Grant-Provided Professional Development was Beneficial, and More is Needed in General

6) Most grant-provided professional development was beneficial

When asked to describe the STEM professional development they had experienced and any aspect(s) that were beneficial, the majority of focus groups every year recalled at least one STEM professional development that was useful. The most common response across all three years described training in which the teachers themselves were able to conduct the STEM activity or lab.

Being able to physically do an activity helps you understand how you could pull this off in your classroom and what things you may have to tweak along the way. (Teacher, Year Two)

One professional development really sticks in my mind ... We actually went around and did the centers to see what it is like for students. It helps you really remember it. (Teacher, Year Three)

7) Teachers recommended that schools and districts provide more STEM professional development

Every year when reflecting broadly on the frequency and type of professional development opportunities available, most teachers explained that they found the offerings severely lacking overall.

I want something specific in my area of concentration. A lot of times we have these staff development things where it’s a broad thing with everyone in there – social studies teachers, science teachers, math teachers, technology teachers. (Teacher, Year Two)
We haven’t really had lots of professional development instructing us [science teachers]. (Teacher, Year Three)

We had math professional development at the beginning of the year, but other than that we really haven’t had anything else. (Teacher, Year Three)

Teachers in Years Two and Three explained that highly beneficial professional development is: led by master teachers instead of individuals with no relevant teaching experience; content- and grade-level specific; and sometimes focused solely on increasing teachers’ own content knowledge. One teacher illustrated:

The most valuable professional development that I’ve gotten is when someone who has actually taught this stuff comes in and shares things that they’ve actually done successfully in their classroom ... We went to a week-long staff development last summer, led by two people from [a North Carolina school district]. They showed us what they actually do in integrated math, because they’ve been doing it for several years. That was the most helpful professional development that I’ve done in the past 15 years. (Teacher, Year Two)

Furthermore, multiple teachers reported that attending professional conferences was very beneficial and that they would benefit from opportunities to attend more.

Going to the regional science conference was a really cool experience. It’s always good to go there and get new ideas, and it’s just good to see different stuff. (Teacher, Year Three)

To grow STEM teachers’ knowledge and skills, the teachers recommended more professional development with the following characteristics:

- Hands-on;
- Content- and grade-level specific;
- Led by master teachers; and
- Providing information for immediate classroom implementation.

**Teachers’ Confidence and Beliefs Regarding Instruction Remained Mostly Stable**

8) Teachers’ felt confident in their teaching abilities; science and mathematics teachers grew slightly more confident from Year One to Year Three

The T-STEM Survey asked science, technology, engineering, and mathematics teachers to indicate their level of agreement with statements like, “I know the steps necessary to teach [content area] effectively” and “I am confident I can answer students’ [content area] questions.”

Every year the vast majority of teachers reported that they either “agreed” or “strongly agreed” with those statements. Mathematics teachers consistently reported having the most confidence in their teaching abilities. Comparing the results by year, findings suggest that from Year One to
Year Two science, mathematics, and technology teachers’ confidence declined slightly, with a larger proportion of teachers “agreeing” in Year Two rather than “strongly agreeing.” From Year Two to Year Three, however, there was a relatively large increase in the proportion of science and mathematics teachers who “strongly agreed” that they felt confident in their teaching abilities.

**Figure 9. Teacher Self-Efficacy and Beliefs by Subject Area and Year***

*The data are cross-sectional, not longitudinal – the exact same teachers did not respond to the survey every year. The compositions of the samples of teachers were demographically similar each year.

**Note:** Responses were recorded on a five-point Likert scale: “strongly disagree” (1), “disagree” (2), “neither agree nor disagree” (3), “agree” (4), and “strongly agree” (5). The sample size for engineering teachers was too small to report. A mean composite score was created for each teacher by averaging their scores on the survey items measuring self-efficacy and beliefs.

9) Teachers’ attitudes toward 21st century learning skills remained positive every year

Results from the T-STEM Survey in Years Two and Three suggest that participating teachers believed teaching students 21st century learning skills, such as communication, collaboration, and self-regulated learning, was very important. The majority of teachers reported that they “strongly agreed” with statements such as, “I believe it is important that students respect the differences of their peers.”

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10 These items were not included in the Year One Pilot T-STEM Survey.
Table 15
Mean Scores of Teacher Attitudes toward 21st Century Learning in Years Two and Three

<table>
<thead>
<tr>
<th>Mean Composite Score</th>
<th>Y2</th>
<th>Y3</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>503</td>
<td>275</td>
</tr>
<tr>
<td>21st century Learning Attitudes</td>
<td>4.4</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Note: Responses were recorded on a five-point Likert scale: “strongly disagree” (1), “disagree” (2), “neither agree nor disagree” (3), “agree” (4), and “strongly agree” (5). A mean composite score was created for each teacher by averaging their scores on the survey items measuring attitudes toward 21st century learning.

10) Teachers remained divided on whether the classroom efforts of teachers, in general, impact student learning

The T-STEM Survey asked science, technology, engineering, and mathematics teachers to indicate their level of agreement with statements such as, “When a student does better than usual in [content area], it is often because the teacher exerted a little extra effort” and “Students’ learning in [content area] is directly related to their teacher’s effectiveness in [content area] teaching.”

Findings overall across Years One, Two, and Three suggest that there was substantial disagreement among teachers regarding the degree to which educators can impact student learning, with some smaller fluctuations within teachers of different instructional areas from year-to-year. On the whole, participating teachers slightly agreed that educators can impact student learning, but a sizable group of teachers reported that they felt ambivalent and “neither agreed nor disagreed.”

Figure 10. Teacher Outcome Expectancy by Subject Area and Year*

*The data are not longitudinal in that the exact same teachers did not respond to the survey every year. The compositions of the samples of teachers were demographically similar each year.

11 The wording of items on the Pilot T-STEM Survey in Year One was slightly different from the wording in Years Two and Three.
Note: Responses were recorded on a five-point Likert scale: “strongly disagree” (1), “disagree” (2), “neither agree nor disagree” (3), “agree” (4), and “strongly agree” (5). A mean composite score was created for each teacher by averaging their scores on the survey items measuring outcome expectancy.

When examined at the survey-item level, results from Year Two and Year Three show that respondents were more likely to agree with statements suggesting that educators’ actions can cause higher-than-expected student learning than statements suggesting lower-than-expected student learning. This is a common phenomenon documented by psychologists and referred to as the social-desirability effect. Also in both years teachers agreed most strongly with the same statements:

- “The inadequacy of a student’s [content area] background can be overcome by good teaching” – 69% (Year Two) and 69% (Year Three) “agreed” or “strongly agreed”
- “If parents comment that their child is showing more interest in [content area] at school, it is probably due to the performance of the child’s teacher” – 59% and 64%
- “When a student’s learning in [content area] is greater than expected, it is most often due to their teaching having found a more effective teaching approach” – 55% and 56%

In Year Two and Year Three teachers were also least likely to “agree” or “strongly agree” with the same statements:

- “If a student’s learning in [content area] is less than expected, it is most likely due to ineffective [content area] teaching” – 23% (Year Two) and 19% (Year Three) “agreed” or “strongly agreed”
- “Minimal student learning in [content area] can generally be attributed to their teachers” – 27% and 20%

*Teachers Recommended Changes for Schools and Districts*

Every year teachers shared recommended changes to school- and district-level operations that they believed would help them be even more effective STEM educators. In addition to more professional development and more funding, the most common recommendations across the three years were:

- *More time for teachers to develop their instructional practice* – so they can develop materials independently and collaborate with colleagues;
- *Reduction in continuous cycle of programmatic changes* – so instead of being in a constant state of professional transition, they can develop deeper, more refined instructional knowledge and practice; and
- *Different scheduling of STEM instructional time* – more time in elementary schools so they can teach STEM, because science frequently had been reduced to once or twice per week and engineering was rarely taught; extended class periods in middle and high schools to allow more time for labs and inquiry-based learning.
IV. Changes in Student Attitudes toward STEM

The Golden LEAF STEM Initiative aimed to improve student attitudes toward STEM. This included, more specifically, their interest and enjoyment in various STEM subjects, their confidence in their skills, and their interest in STEM careers. The lab materials, digital probes, robotics materials, field trips, and other grant activities were designed to achieve these goals.

The S-STEM Survey was administered to students in Years One (pilot survey), Two, and Three and asked students to report about their confidence in various STEM subjects, interest in multiple STEM careers, and their expectations for their academic future. Individual focus groups were conducted with teachers from each grant in Years One, Two, and Three, and with students in Year Three to complement the survey findings and gather detailed descriptions of any changes in student attitudes or learning. Synthesized findings from the surveys and focus groups are summarized below, and suggest that grant activities contributed to:

- A slight increase in student attitudes toward STEM;
- Increases in student interest in STEM careers;
- Increases in student engagement during STEM lessons; and
- Increases in students’ 21st century skills, especially problem-solving and collaboration.

**Student Attitudes toward STEM Subjects Improved Slightly**

1) Student attitudes toward mathematics and science increased somewhat; attitudes toward engineering and technology remained constant

The Upper Elementary and Middle/High S-STEM Surveys asked students to agree or disagree with statements such as, “I feel good about myself when I do science” and “I am interested in what makes machines work.” Results indicate that student attitudes toward mathematics and science were slightly positive and increased somewhat from Year One to Year Three (mean scores of 3.6 and 3.8 respectively for math; 3.4 and 3.5 for science). Increases in the positivity of attitudes toward mathematics were especially pronounced among upper elementary school students and high school students (0.2 units in the mean scores). Students’ attitudes toward engineering and technology remained constant from Year One to Year Three.
Table 16
Mean Composite Scores of Student STEM Attitudes by School-Level in Years One and Three

<table>
<thead>
<tr>
<th>STEM Attitudes</th>
<th>Upper Elementary</th>
<th>Middle School</th>
<th>High School</th>
<th>All Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Y1</td>
<td>Y3</td>
<td>Y1</td>
<td>Y3</td>
</tr>
<tr>
<td>n</td>
<td>785</td>
<td>2,375</td>
<td>7,698</td>
<td>8,255</td>
</tr>
<tr>
<td>Math Attitudes</td>
<td>3.7</td>
<td>3.9</td>
<td>3.6</td>
<td>3.7</td>
</tr>
<tr>
<td>Science Attitudes</td>
<td>3.6</td>
<td>3.5</td>
<td>3.4</td>
<td>3.5</td>
</tr>
<tr>
<td>Engineering and Technology Attitudes</td>
<td>3.5</td>
<td>3.6</td>
<td>3.4</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Note: Results reported only for students who responded to all three attitudes sections. Responses were recorded on a five-point Likert scale: “strongly disagree” (1), “disagree” (2), “neither agree nor disagree” (3), “agree” (4), and “strongly agree” (5). A mean composite score was created for each student by averaging their scores on the survey items measuring attitudes toward STEM. Upper elementary results include students in grades 4-5; middle school results include students in grades 6-8; and high school results include students in grades 9-12.

2) Females consistently had less positive attitudes toward engineering and technology than males

One of the most significant findings from all of the student survey data indicates that female attitudes toward engineering and technology (3.2 in Year Three) were dramatically lower than male attitudes (3.7). This differential is by far the largest differential found among all comparisons by gender, race/ethnicity (there is very little variation by race/ethnicity), or school-level within all three years of survey data. Furthermore, this finding is supported by results from the survey section asking students to report their level of interest in engineering careers (see page 30). It is notable, however, that female students’ attitudes toward engineering and technology increased at a slightly higher rate than male students’.
Figure 11. Mean Composite Scores of Student STEM Attitudes by Gender in Years One and Three*

![Graph showing mean composite scores by gender and year](image)

*The data are not longitudinal in that the exact same students did not respond to the survey every year. The compositions of the samples of students were demographically similar each year.

Note: Results reported only for students who responded to all three attitudes sections. Responses were recorded on a five-point Likert scale: “strongly disagree” (1), “disagree” (2), “neither agree nor disagree” (3), “agree” (4), and “strongly agree” (5). A mean composite score was created for each student by averaging their scores on the survey items measuring attitudes toward STEM.

3) Students maintained positive attitudes toward 21st century learning skills every year

In North Carolina many current and future jobs will require employees with an advanced set of general skills in critical-thinking, communication, and collaboration – often referred to as “21st century skills” (North Carolina Commission on Workforce Development, 2011; Partnership for 21st Century Skills, 2004). Results from the Upper Elementary and Middle/High S-STEM Survey suggest that students had more positive attitudes toward 21st century learning skills, such as communication, collaboration, and self-regulated learning, than toward STEM subjects. This trend was consistent every year.

Table 17
Mean Scores of Student Attitudes toward 21st Century Learning in Years One, Two, and Three

<table>
<thead>
<tr>
<th></th>
<th>Mean Composite Score</th>
<th>Y1</th>
<th>Y2</th>
<th>Y3</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>9,686</td>
<td>11,843</td>
<td>11,292</td>
<td></td>
</tr>
<tr>
<td>21st century Learning Attitudes</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td></td>
</tr>
</tbody>
</table>

Note: Responses were recorded on a five-point Likert scale: “strongly disagree” (1), “disagree” (2), “neither agree nor disagree” (3), “agree” (4), and “strongly agree” (5). A mean composite score was created for each student by averaging their scores on the survey items measuring attitudes toward 21st century learning.
While this survey section’s results are most powerful and accurate at the composite-level, as shown above, the individual survey items specifically related to communication and collaboration provide some detailed insight. Interestingly, there was slight drop-off in the proportion of middle/high school students who “agreed” or “strongly agreed” with these items from Year One to Year Three. In that period of time teacher focus groups suggest that teachers thought students were learning more collaboration skills and students reported enjoying group work. The cause of the negative correlation between these findings is unknown; however, one hypothesis is that the negative correlation is caused by either an implementation dip or response shift bias.12

Table 18
Student Confidence in Collaboration Skills by School-Level in Years One and Three

<table>
<thead>
<tr>
<th>Survey Item</th>
<th>Proportion “Agree/Strongly Agree”</th>
<th>Upper Elementary</th>
<th>Middle and High</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Y1 Y3</td>
<td>Y1 Y3</td>
<td></td>
</tr>
<tr>
<td>I can lead others to reach a goal.</td>
<td>69% 74%</td>
<td>73% 73%</td>
<td></td>
</tr>
<tr>
<td>I like to help others do their best.</td>
<td>86% 85%</td>
<td>80% 79%</td>
<td></td>
</tr>
<tr>
<td>I respect all children my age even if they are different from me.</td>
<td>80% 83%</td>
<td>85% 82%</td>
<td></td>
</tr>
<tr>
<td>I try to help other children my age.</td>
<td>83% 83%</td>
<td>82% 80%</td>
<td></td>
</tr>
<tr>
<td>When I make decisions, I think about what is good for other people.</td>
<td>72% 73%</td>
<td>78% 76%</td>
<td></td>
</tr>
<tr>
<td>When things do not go how I want, I can change my actions for the better.</td>
<td>70% 70%</td>
<td>78% 75%</td>
<td></td>
</tr>
<tr>
<td>I can work well with all students, even if they are different from me.</td>
<td>73% 75%</td>
<td>76% 75%</td>
<td></td>
</tr>
</tbody>
</table>

Note: Responses only from students who answered every question were used. The wording of the survey items was taken from the Upper Elementary S-STEM Survey. Responses were recorded on a five-point Likert scale: “strongly disagree” (1), “disagree” (2), “neither agree nor disagree” (3), “agree” (4), and “strongly agree” (5).

Student Interest in STEM Careers Increased

4) Student interest in every STEM career area increased from Year One to Year Three except in “Medicine”; the greatest increase in interest was in “Computer Science”.

When asked to indicate their level of interest in various STEM career areas, the average proportion of students who reported that they were either “interested” or “very interested” increased from Year One to Year Three in all career areas except “medicine” (50% in Year One and 49% in Year Three). In the following five career areas the proportion of students interested grew the most, by five or more percentage points:

12 An implementation dip is dip in performance and confidence as a person encounters an innovation that requires new skills and new understandings. Response shift bias occurs when a respondent’s awareness or knowledge shifts as a result of the intervention, and therefore their internal metric or standard of measurement also shifts.
Golden LEAF STEM Initiative
June 2015

- computer science (8% points);
- earth science (6% points);
- energy (6% points); and
- chemistry (5% points).

Table 19
Student Interest in STEM Careers in Years One and Three

<table>
<thead>
<tr>
<th>Career Area</th>
<th>Proportion “Interested/Very Interested”</th>
<th>Y1 (9,412)</th>
<th>Y3 (10,972)</th>
<th>(Y3 – Y1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veterinary Work</td>
<td></td>
<td>51%</td>
<td>53%</td>
<td>2%</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td>50%</td>
<td>53%</td>
<td>3%</td>
</tr>
<tr>
<td>Biology &amp; Zoology</td>
<td></td>
<td>48%</td>
<td>50%</td>
<td>2%</td>
</tr>
<tr>
<td>Medicine</td>
<td></td>
<td>50%</td>
<td>49%</td>
<td>-1%</td>
</tr>
<tr>
<td>Computer Science</td>
<td></td>
<td>37%</td>
<td>45%</td>
<td>8%</td>
</tr>
<tr>
<td>Medical Sciences</td>
<td></td>
<td>42%</td>
<td>42%</td>
<td>0%</td>
</tr>
<tr>
<td>Chemistry</td>
<td></td>
<td>38%</td>
<td>43%</td>
<td>5%</td>
</tr>
<tr>
<td>Earth Science</td>
<td></td>
<td>35%</td>
<td>41%</td>
<td>6%</td>
</tr>
<tr>
<td>Mathematics</td>
<td></td>
<td>37%</td>
<td>41%</td>
<td>4%</td>
</tr>
<tr>
<td>Environmental Work</td>
<td></td>
<td>38%</td>
<td>40%</td>
<td>2%</td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td>33%</td>
<td>39%</td>
<td>6%</td>
</tr>
<tr>
<td>Physics</td>
<td></td>
<td>30%</td>
<td>33%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Note: Sample size n represents the number of students who responded at least one career interest question. Responses were recorded on a four-point Likert scale: “not at all interested” (1), “somewhat interested” (2), “interested” (3), and “very interested” (4).

5) Male and female student interest in STEM careers grew in most career areas; male student interest in STEM careers grew slightly more than females

Male student interest in STEM careers grew, on average, by 4.3% points from Year One to Year. Female students’ interest grew, on average, by 2.6% points (figures are rounded in table below).

From Year One to Year Three the proportion of female students interested grew in all career areas except in: “medicine” (62% in Year One and 58% in Year Three), “medical sciences” (50% and 49%), “veterinary work” (no change), and “biology and zoology” (no change). The proportion of female students interested grew the most from Year One to Year Three, by five or more percentage points, in the following career areas: “engineering” (6% points); “computer science” (6% points); “energy” (6% points); and “chemistry” (5% points).

The proportion of male students interested grew in all career areas except in: “engineering” (no change). The proportion of male students interested grew the most, by five or more percentage
points, in the following career areas: “computer science” (8% points); “chemistry” (7% points); “earth science” (7% points); and “energy” (5% points).

Figure 12. Female student percent “interested” or “very interested” in STEM careers, by Year

Note: Responses were recorded on a four-point Likert scale: “not at all interested” (1), “somewhat interested” (2), “interested” (3), and “very interested” (4).
6) Female and male student interests in STEM careers grew slightly more similar

Female and male students’ levels of interest in STEM careers grew slightly more similar overall from Year One to Year Three—in some career areas female interest decreased while male interest increased, or vice versa. The largest changes in the differentials between females and males were in the following fields:

- **Medicine** – 9% point change in the differential, with female interest decreasing and male interest increasing
- **Engineering** – 6% point change, with female interest increasing and male interest remaining constant; and
- **Biology and Zoology** – 4% point change, with female interest remaining constant and male interest increasing.
Table 20

Student Interest in STEM Careers by Gender in Years One and Three

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female Y1</td>
<td>Female Y3</td>
</tr>
<tr>
<td>n</td>
<td>4,685</td>
<td>5,378</td>
</tr>
<tr>
<td>Veterinary Work</td>
<td>66%</td>
<td>66%</td>
</tr>
<tr>
<td>Engineering</td>
<td>28%</td>
<td>34%</td>
</tr>
<tr>
<td>Biology &amp; Zoology</td>
<td>55%</td>
<td>55%</td>
</tr>
<tr>
<td>Medicine</td>
<td>62%</td>
<td>58%</td>
</tr>
<tr>
<td>Computer Science</td>
<td>26%</td>
<td>32%</td>
</tr>
<tr>
<td>Medical Sciences</td>
<td>50%</td>
<td>49%</td>
</tr>
<tr>
<td>Chemistry</td>
<td>34%</td>
<td>39%</td>
</tr>
<tr>
<td>Earth Science</td>
<td>33%</td>
<td>38%</td>
</tr>
<tr>
<td>Mathematics</td>
<td>34%</td>
<td>37%</td>
</tr>
<tr>
<td>Environmental Work</td>
<td>39%</td>
<td>40%</td>
</tr>
<tr>
<td>Energy</td>
<td>19%</td>
<td>25%</td>
</tr>
<tr>
<td>Physics</td>
<td>21%</td>
<td>25%</td>
</tr>
<tr>
<td>Average</td>
<td>39%</td>
<td>42%</td>
</tr>
</tbody>
</table>

Note: Sample size n represents the number of students who responded at least one career interest question. Responses were recorded on a four-point Likert scale: “not at all interested” (1), “somewhat interested” (2), “interested” (3), and “very interested” (4).

7) Asian students’ interest in STEM careers was highest every year and White/Caucasian students’ interest was lowest

When compared by racial/ethnic groups, the highest proportion of students “interested” or “very interested” in STEM careers, averaged across the 12 career areas, was among students who self-identified as Asian. This trend was consistent across Years One, Two, and Three. The lowest average proportion of students “interested” or “very interested” in STEM careers was among students who self-identified as White/Caucasian.13

Analyzing the proportions of students interested in specific STEM career areas, results indicate that more Asian students were “interested” or “very interested” in the following career areas compared to all others in Years One, Two, and Three: medicine, computer science, biology and zoology, earth science, and chemistry. More Black/African American students were “interested” or “very interested” in mathematics compared to other students every year.

Conversely, fewer White/Caucasian students were “interested” or “very interested” in the following careers compared to other students in Years One, Two, and Three: computer science,

13 For Year One data see Corn et al., 2012 and for Year Two data see Faber et al., 2013.
energy, and chemistry. Fewer Black/African American students were interested in biology and zoology, veterinary work, and environmental work compared to other students every year.

**Figure 14. Student Interest in STEM Careers by Race/Ethnicity in Year Three – By Proportion “Interested” or “Very Interested”**

Note: Responses were recorded on a four-point scale: “Not At All Interested” (1), “No So Interested” (2), “Interested” (3), and “Very Interested” (4).

8) **Interest in STEM career areas was lower among students in higher school-levels**

Every year, higher proportions of students in upper elementary school reported being “interested” or “very interested” in STEM career areas, on average, than students in middle school and high school. Also every year higher proportions of students in middle school reported being “interested” or “very interested” in STEM career areas, on average, than students in high school.
It is important to note here that the grant interventions at the high school level tended to be less comprehensive than the interventions at the middle and elementary school levels.

Figure 15. Average Student Interest across Twelve STEM Career Areas by School-Level and Year

About Half of All Students Plan to Take Advanced Classes and Many Want More Options

9) 47% of students intended to take advanced mathematics courses; females were slightly more likely to intend to take advanced mathematics than males

In both Year One and Year Three just under half (48%) of all students reported plans to take advanced mathematics courses. In both years, when compared by gender, female students were slightly more likely to plan to take advanced mathematics courses than males.

Table 21
Middle and High School Students’ Intentions to take Advanced Mathematics Classes by Gender in Years One and Three

<table>
<thead>
<tr>
<th>In the future, do you plan to take advanced classes in mathematics?</th>
<th>Proportion of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
</tr>
<tr>
<td></td>
<td>Y1</td>
</tr>
<tr>
<td>n</td>
<td>3,892</td>
</tr>
<tr>
<td>Yes</td>
<td>50%</td>
</tr>
<tr>
<td>No</td>
<td>19%</td>
</tr>
<tr>
<td>Not Sure</td>
<td>31%</td>
</tr>
</tbody>
</table>

*Note: The Upper Elementary S-STEM Survey did not contain this item.*
Also, when compared by race/ethnicity, students who self-identified as Asian were the most likely to plan to take advanced mathematics classes, as were Black/African Americans in Year Two. In Year Two and Year Three American Indian/Alaska Native students were least likely to be planning to take advanced mathematics courses.

10) 44% of students intended to take advanced science courses

In both Year One and Year Three about 44% of all students planned to take advanced science courses. When compared by gender, students reported similar intentions.

When compared by race/ethnicity, in Year Two students who self-identified as White/Caucasian were most likely to report plans to take advanced science classes and in Year Three students who self-identified as Asian were. In Year Two students who self-identified as Hispanic/Latino were least likely to plan to take advanced science classes and in Year Three Black/African American students were.

Table 22
Middle and High School Students’ Intentions to take Advanced Science Classes by Race/Ethnicity and Year

<table>
<thead>
<tr>
<th>In the future, do you plan to take advanced courses in science?</th>
<th>n</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Y2</td>
<td>Y3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td>Not Sure</td>
<td>Yes</td>
<td>No</td>
<td>Not Sure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>American Indian/Alaska Native</td>
<td>262-265</td>
<td>40%</td>
<td>26%</td>
<td>34%</td>
<td>44%</td>
<td>24%</td>
<td>32%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>156-247</td>
<td>41%</td>
<td>17%</td>
<td>42%</td>
<td>48%</td>
<td>13%</td>
<td>39%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black/African American</td>
<td>821-870</td>
<td>39%</td>
<td>27%</td>
<td>33%</td>
<td>43%</td>
<td>26%</td>
<td>31%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White/Caucasian</td>
<td>5,038-5,523</td>
<td>45%</td>
<td>19%</td>
<td>36%</td>
<td>44%</td>
<td>22%</td>
<td>35%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic/Latino</td>
<td>926-1,131</td>
<td>39%</td>
<td>19%</td>
<td>42%</td>
<td>42%</td>
<td>21%</td>
<td>37%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiracial</td>
<td>309-468</td>
<td>40%</td>
<td>24%</td>
<td>36%</td>
<td>45%</td>
<td>23%</td>
<td>32%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The Upper Elementary S-STEM Survey did not contain this item.

11) Vast majority of students wanted opportunities to take more STEM courses

During focus groups in Year Three students were asked, “What, if anything, do you wish you had at your school regarding learning opportunities in science, technology, engineering, or math?” Students in 11 out of the 13 focus groups mentioned wanting access to more diverse and/or advanced STEM courses, such as:
• Advanced Placement (AP) courses in Biology, Calculus, Chemistry, Environmental Science, and Physics;
• Project Lead the Way courses; and
• General courses in agricultural engineering, robotics, computer design, computer programming, video design, and courses that integrate STEM with the arts.

These interesting results, in which only about half of all surveyed students indicated plans to take advanced courses in mathematics and science but 11 out of 13 focus groups reported interest in taking more STEM courses, need further investigation. Possible explanations include different interpretations of the question by the students – the focus group question used the term “STEM courses” and was asked in the context of a conversation about learning activities, whereas the survey questions used the specific terms “advanced mathematics” and “advanced science” and allowed only for “yes, no, not sure” responses. Alternatively, the difference in these findings could be a result of selection effects – the students participating in the focus groups may have been slightly more interested in STEM overall (although teachers were asked to provide a diverse group of student participants).

V. Changes in Student Learning in STEM

The most direct way student learning across the varying interventions was measured was through focus groups with teachers in Years One, Two, and Three, and focus groups with students in Year Three. The strongest findings from this data suggest that as a result of initiative activities:

• Student engagement in STEM content increased;
• Students’ collaboration skills improved;
• Students’ problem-solving skills improved; and
• Students acquired deeper learning.

Student Engagement Increased

1) Student engagement increased

Broadly, student engagement is understood as the degree of attention, curiosity, interest, and optimism that students show when they are learning or being taught. Decades of education research has identified student engagement as an important pre-requisite for learning. Findings from focus groups with teachers, focus groups with students, interviews with grant coordinators, and classroom observations suggest that the hands-on, inquiry-based STEM activities led to increases in student engagement.

Each year when teachers were asked whether or not they had noticed any changes in student engagement as a result of hands-on, inquiry-based activities, teachers in every one of the focus groups (39 total) stated, often emphatically, that they had noticed increased student engagement.
I think this is the highest level of student engagement I’ve ever experienced, as far as teaching. (Teacher, Year Two)

I can tell a huge difference when we’re doing an inquiry-based lesson ... It’s a totally different class. They’re all discussing. They’re all working together. They’re trying to solve the problems ... You don’t see the type of off-task behaviors in class, because they are engaged. (Teacher, Year Two)

Anytime you’re doing anything that’s hands-on where they get to figure something out on their own, as opposed to a teacher standing in front of a classroom telling them, or the students reading it in a textbook - and all those things have their place - it’s a totally different level of engagement. (Teacher, Year Three)

Every year grant coordinators were also asked the same question about changes in student engagement. While many indicated that they were no in the classroom regularly enough to be able to answer the question, a few indicated that they noticed increased student engagement. One coordinator described:

Rather than the lectures and the reading, the kids are more actively learning about science and so that’s brought some excitement into the science classrooms. When you go into walk through the kids are up, they’re engaged, they’re learning, they’re talking about science, they’re writing about science. (Grant Coordinator, Year Three)

Importantly, students in every focus group in Year Three, when asked to describe their favorite kinds of activities in their science, mathematics, engineering, and technology classes, overwhelmingly indicated that they most enjoyed hands-on activities.

I like the experiments the most because I feel like we’re actually learning more than with other stuff. Before, in elementary school, they told us what the scientific method was but we didn’t do any experiments to use it. Now, not only are we learning about the elements, but we’re learning so many other aspects of science too - like how to accurately conduct an experiment. (Student, Year Three)

When we did the gel electrophoresis that was really cool. We got to use iPads and we used manual ones where you could actually set the dial and then push a button. That was really cool to use it instead of just talk about it. Once we got our gels back we analyzed them and found out who was the suspect in the crime scene. It's really fun; it’s a lot more hands-on. (Student, Year Three)

2) Student engagement increased among learners not served as well by traditional instruction

In Year One teachers were not directly asked to reflect on students who struggle in school, however, in several focus groups the teachers independently highlighted increased engagement among learners not served as well by traditional instruction.

There are a lot of students that just simply hate school. They do not want to go to school. They don’t care about it. For them, it's just a pain, something they have to do. But for a
lot of those same students, when they come into this class, this is something they want to do. They want to come and they want to work on things. (Teacher, Year One)

Based on these Year One responses, in Year Two and Three the evaluation team gently inquired about whether or not teachers noticed any changes among any particular type of student. A majority of teachers described that they noticed changes among:

- Mechanical and visual learners;
- Struggling students,
- Low-readers, and/or
- Students who were learning English as a second language.

Teachers described:

When you start talking about differentiating learning, I think this is so hands-on that it reaches your visual people, it reaches the kinesthetic learners. It uses all those different methods. (Teacher, Year One)

Our Hispanic/Latino population loves the hands-on activities. A lot of them are English as a Second Language learners, so if you hand them a science book and say, ‘Read this,’ they can only stare at the page. (Teacher, Year Two)

At this school we have a high number of children from low socio-economic status families, all socially disadvantaged ... One of the things I love about science is that it does engage those kids, and sometimes those kids are the toughest to get through to because they’ve got all kinds of life distractions that make it hard for them to learn. Also for children with learning disabilities hands-on activities are more accessible to them ... this kind of science is really important. (Teacher, Year Three)

It doesn’t discriminate against reading ability. We have some of the lowest readers in Project Lead the Way and it’s amazing what they can do when they get their hands on stuff. Their reading ability hinders them in math and science, but it doesn’t hinder them in that class. It's great to see a kid get to shine. (Teacher, Year Three)

3) Informal or extracurricular learning opportunities increased student engagement every year

Results from several grant coordinator interviews, a few teacher focus groups, and a few student focus groups suggest that various afterschool clubs and summer or weekend STEM camps increased levels of student participation and excitement in STEM – both indicators of behavioral and emotional engagement. Several Golden LEAF STEM Initiative grants, for example, used their funds to either create their own summer STEM camps or to send groups of students to already established camps, like robotics camps or others.

For those who attend the STEM camp, they are excited that they have a better understanding of the curriculum because they had exposure to it during the summer. (Grant Coordinator, Year Two)
We’ve got robotics, we’ve got a STEM club, the Science Olympiad – these are things we weren’t even uttering three years ago. (Grant Coordinator, Year Three)

We have worked really hard to raise the academics to the same level of excitement as athletics. I think the Science Festival was a good example of that … I think that’s probably been our biggest success: raising academic focus to where it was as valued as athletics. (Grant Coordinator, Year Three)

I really enjoy robotics because I like how it’s not like in science class or in math class when you normally have a hypothetical situation. With robotics you actually have to find a way to solve this problem and then build something that will actually do it for you. (Student, Year Three)

4) Industry-related activities increased student engagement and provided valuable career information for students

With the goal of increasing student interest in STEM subjects and careers, some of the Golden LEAF STEM Initiative grants provided opportunities for students to directly engage with STEM industry professionals and facilities. The activities included: tours of regional STEM industry facilities; presentations and demonstrations by STEM industry professionals; and, in the case of one grant, an elective class in which students used professional-grade equipment for projects and competitions. In interviews and focus groups with participants in these particular grants, several coordinators, teachers, and students described how the industry interactions increased student interest in STEM subjects and careers.

After the tour at [a local community college] I had about 10 kids come to me excited saying, "Yeah, I really want to do this.” I had three kids who came to me and said, "I know what I want to be now." That's very exciting. (Teacher, Year Two)

One student noted that, in addition to having professionals come to the schools, she also wanted more opportunities to visit professionals in their work setting.

I agree with what she said about having more professionals come in. I’d also like to go out and experience it, you know, maybe sit off to the side but get to watch it happening. Because how they explain it in a book may not be what it's really like. (Student, Year Three)

Students’ 21st Century Skills, Including Problem-Solving and Collaboration, Increased

Employers want to hire employees with an advanced set of general skills in critical-thinking, communication, and collaboration, or 21st century skills. Results from focus groups with teachers and with students indicate that students gained knowledge and skills in these areas through the small-group work that characterized most of the hands-on, inquiry-based learning activities.
5) Students’ problem-solving skills increased

In Year One teachers were asked “whether or not they noticed any changes in student learning as a result of using hands-on, inquiry-based activities.” In several focus groups the teachers explained that they noticed increases in students’ problem-solving skills.

I can see a big improvement in my kids breaking apart a problem and using different strategies. (Teacher, Year One)

A lot of times I think kids think there’s a box that they have to be in, and now I think they’ve learned what real true experimenting is - the purpose of experimenting and the purpose of really walking through problem-solving issues. (Teacher, Year One)

Based on this Year One finding, in Years Two and Three teachers were gently asked whether or not they happened to notice any changes in student problem-solving skills. Teachers in almost every focus group in both years agreed that they had.

The students are starting to gradually shift into a frame of mind in which learning is not about an answer any more – it’s about how you got there and what does the answer mean. (Teacher, Year Two)

I think it definitely makes them think more critically – when they have to apply what they know to the lab to try to figure out the answer. They love coming to hypothesis and things, they really get into that. I definitely think it makes them think more critically and it makes them dig a little deeper. (Teacher, Year Three)

It used to be the dirty dozen labs - you’d do them straight by the report and you got the results you were supposed to get. Now it is: let the kids design the labs; let them interpret their results and figure out if they made a mistake and then how to do it again the right way. I think labs and these SEPUP materials and all the different things that we do - they learn so much about how to apply and integrate the stuff we’ve learned to solve problems. (Teacher, Year Three)

By the time we go through with the design process and problem-solving process and they get towards the end of the class, they’re really more proficient at it. They can explore many different options and then pick the best one, instead of trying to find the right answer right off the bat. (Teacher, Year Three)

6) Students’ collaboration skills increased

The vast majority of participating teachers implemented the hands-on, inquiry-based STEM activities by having students work in small groups or teams. Teachers were never directly asked to reflect on student collaboration skills, and yet every year teachers in several focus groups highlighted increased collaboration skills as a result from the STEM activities. They especially noticed that students were learning important communication skills.
There is more group work every day and they don’t get to pick who they’re paired with ... So it’s kind of like a real job ... They have to be able to communicate effectively with this person because it’s not just their grade; it’s a group grade. (Teacher, Year One)

The students learn to look at things from different points of view. They have the ability to sit not in a row, but to look across the table and ask, “What do you think,” or to be put in different groups that they’re not comfortable with and figure it out. (Year Two, Teacher)

It’s a lot of hands-on, they collaborate in groups -it’s how they would be working in the 21st century workplace. They learn to collaborate with each other, to get along, and when somebody has a different opinion they need to work it out. It's been really a good program from my point of view. (Teacher, Year Three)

7) Students learned more when they worked in groups and enjoyed the activities more

In Year Three when students were asked, “What kinds of activities help you learn the best,” many students described how working in small groups helped them learn best. They explained that not only learned more, but also they enjoyed working in groups more too.

I like the group work because my partners can help me if I’m struggling with something. (Student, Year Three)

In Earth Science with a project that we did ... I probably would have procrastinated but since I had other group members relying on me, that kind of motivated me to be able to do it. So with some things, like big projects, it helps having a group. (Student, Year Three)

I think group work is more enjoyable, because it’s easier to ask questions of one of your friends versus a teacher, because a teacher is constantly running everywhere answering everybody’s questions. (Student, Year Three)

It’s just that we have fun doing it with groups or partners. We’re learning but we just don’t know it because we’re having fun. (Student, Year Three)

A few students did state that in addition to hands-on, inquiry-based activities, sometimes note-taking or listening helped them best learn the material.

8) Students acquired deeper learning

In Year Three participating students were asked, “What kinds of activities help you learn the best?” The majority of students indicated that hands-on activities not only were their favorite activities, but that they also helped them learn the best. Many times students explained that the activities were their favorite specifically because they helped them learn better.

Whenever you use hands-on stuff you can figure out, "Hey when I use this, it works," and "When I use that it don’t work." You can mix or match and see what works best for you and usually it helps you remember things quite a bit better. (Student, Year Three)
I think the hands-on activities help me learn best when you actually have hands-on work where you have to figure things out and it helps you learn, instead of just "to solve this problem you do this and this and then this." (Student, Year Three)

I need to be able to see it and move it myself and I need to be able to hear somebody explain to me. I can’t read it and then understand it; I have to hear somebody explain it and actually, physically, see it. (Student, Year Three)

Similarly, when teachers were asked if they had noticed any changes in student learning as a result of hands-on, inquiry-based activities, a few teacher focus groups in Year One and several teacher focus groups in Year Three indicated that the activities led to deeper student learning.

I think with science, if you can’t see it it’s hard to understand. So when they really get their hands on it and participate in the centers and things they gain a deeper understanding. (Teacher, Year Three)

It makes it more real. I think more learning is taking place, especially with those abstract concepts. (Teacher, Year Three)

VI. Additional Findings

Two data-sets that did not directly answer evaluation questions, but were deemed important nonetheless, were collected. In Years Two and Three a first and second Pilot Principal Leadership for STEM (P-STEM) Survey was administered. This was intended to collect important contextual data about the schools being served – principals have been found by many researchers to be very important in-school factors for learning. It is important to note that principals received no specific STEM education professional development and were not a focus of the Golden LEAF STEM Initiative work.

The second data-set collected was grant coordinators’ responses to the following reflective questions:

• What are the top 1 or 2 lessons you’ve learned about implementing a STEM teaching and learning program?
• What activities do you plan on continuing once grant funding is over?
• If you could have future funding for any STEM teaching and learning activity, what would that activity be?

Principals Provided General Education Leadership

The Pilot P-STEM Survey asked principals to reflect on their leadership of STEM education at their school. The Year Three version asked principals to report their level of agreement with statements about general education leadership practices as they relate to STEM education work, such as, “Regarding the Golden LEAF STEM project/work at my school, I make sure teachers have access to instructional technology tools that facilitate their work (e.g. laptops, digital projectors, software, virtual applications, learning management systems, etc.).” The Year Three
Pilot P-STEM Survey also asked principals to report their level of agreement with statements about STEM education leadership more specifically, such as “Regarding the Golden LEAF STEM project/work at my school, I maintain strategic partnerships with STEM industries” or “I provide consistent professional development specific to the STEM program.” Findings from the Year Three administration suggest that principals were more likely to support teachers through general education leadership practices than through practices specific to STEM education leadership (see Table 24). More detailed results from the P-STEM Survey can be found in Appendix O.

Table 23
School Characteristics Reported by Golden LEAF STEM Initiative Principals

<table>
<thead>
<tr>
<th>My school is …</th>
<th>Proportion (n = 113)</th>
</tr>
</thead>
<tbody>
<tr>
<td>School-level</td>
<td></td>
</tr>
<tr>
<td>Upper Elementary</td>
<td>46%</td>
</tr>
<tr>
<td>Middle</td>
<td>37%</td>
</tr>
<tr>
<td>High</td>
<td>12%</td>
</tr>
<tr>
<td>Proportion FRL*</td>
<td></td>
</tr>
<tr>
<td>26-50%</td>
<td>19%</td>
</tr>
<tr>
<td>51-75%</td>
<td>48%</td>
</tr>
<tr>
<td>76-100%</td>
<td>31%</td>
</tr>
<tr>
<td>School-size</td>
<td></td>
</tr>
<tr>
<td>0 – 300</td>
<td>11%</td>
</tr>
<tr>
<td>300 – 600</td>
<td>63%</td>
</tr>
<tr>
<td>600 – 1,000</td>
<td>22%</td>
</tr>
<tr>
<td>1,000 – 1,500</td>
<td>4%</td>
</tr>
</tbody>
</table>

Note: Free and Reduced Price Lunch Program for students, who qualify based upon their family’s income.

Table 24
Principal Leadership for General Education and STEM Education

<table>
<thead>
<tr>
<th></th>
<th>Average Proportion Agree/Strongly Agree (n = 113)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Education Leadership</td>
<td>89%</td>
</tr>
<tr>
<td>STEM Education Leadership</td>
<td>68%</td>
</tr>
</tbody>
</table>

Note: “General Education Leadership” = 18 items. “STEM Education Leadership” = 19 items.
Grant Coordinators Believed the Work was Successful and Learned Key Strategies for Successful STEM Education

1) Primary implementation successes included industry connections, emergent STEM culture, and expanded STEM work

During interviews grant coordinators were asked to share what they thought were the primary successes of their Golden LEAF STEM Initiative grant. Analysis of the data revealed that in addition to changes in teacher instructional practices and increases in student engagement, by far the most common successes reported were: an increase in connections with STEM industries; emerging STEM cultures; and catalysts for new work.

- **Industry connections:** In addition to changes in teacher instructional practices and increases in student engagement, the most common success discussed was an increase in connections with STEM industries. Grant coordinators described that within the school system the industry connections broadened teachers understanding of STEM career fields and raised student awareness of STEM careers. For the industries, the grant coordinators believed that the connections improved their understanding of public school operations.

  The value of bringing in that community network, from community colleges to the business community, that’s been so strong. That has really broadened our teachers’ understanding of where their knowledge applies beyond the classroom. I think that if you’re going to talk about STEM and its relevance to the world, you can’t do that just within your four walls; you’ve really got to engage with the community around you. And so I think that’s how powerful those relationships have been. (Grant Coordinator, Year Three)

- **Emergent STEM cultures:** A few grant coordinators highlighted the emergence of broader STEM cultures in their schools and communities as a major success. This theme is consistent with a similar finding in Year Two from both grant coordinators and teachers.

  The students can talk about math and science and they can get up and explain it, and it’s all okay. People don’t judge. It used to be that some kids made fun of those who tried to get up and explain, and I don’t see that as much anymore, because everybody is going this way. Kids, teachers, the whole culture is changing, and I think that’s probably the most beneficial thing that I’ve seen. (Teacher, Year Two)

  It really seems like a project that has snowballed, because there is so much interest and excitement about it. I don’t want to say you can’t fail with it, but there are so many good things you could do to precipitate more excitement and more engagement and more partnership, it just seems like an endless round of success … It’s almost more than I can even keep in a notebook, the things that are going on in the schools, because everybody is so excited about it. (Grant Coordinator, Year Two)

  Authentic, project-based learning has occurred across curricula in every single classroom, once each semester; in some classrooms, even more to almost a total
program of project-based learning. This is a huge, a huge cultural difference. (Grant Coordinator, Year Three)

- **Catalysts for new STEM work:** Multiple grant coordinators described that a primary success was the way in which the grant activities had become catalysts for additional STEM work. For example, one coordinator described how a tour of a nearby college, a tour sponsored by the Golden LEAF STEM Initiative, led to plans for expanded collaboration between the district and the college.

2) **Primary implementation challenges included staff turnover, lack of future resources, and grant management**

During interviews grant coordinators were asked to identify the primary challenges related to implementation of their Golden LEAF STEM Initiative grant. Analysis of the data revealed that persistent challenges include: grant management; staff turnover; and lack of resources.

- **Grant management:** About half of all coordinators described that grant management, communication among grant leaders, and/or reporting had been a primary challenge.

- **Staff turnover:** About half of all coordinators explained that staff turnover at the teacher and principal position had been one of their most significant barriers. This was consistent with information grant coordinators shared in Year Two.

- **Lack of resources for STEM education:** The third most common challenge reported was a lack of resources for STEM education. Coordinators said it was sometimes challenging to find transportation funds for industry visits. One coordinator explained that their district lacked funds for media staff and instructional technology support staff. Another worried about being able to sustain a single, full-time STEM instructional coach, a position which they considered critical to the success of their work thus far.

3) **Several key lessons were learned for successfully implementing K12 STEM education programs**

Grant coordinators were asked to share key pieces of advice they would give to leaders of other STEM education programs, based on their own experiences implementing STEM programs. The coordinators offered the following recommendations:

- **Provide effective professional development:** Provide professional development in STEM instruction that first identifies teachers’ differing levels of knowledge and skill, and then builds from those indicators. Be sure to provide teachers time to process and practice their new knowledge.

- **Build buy-in early:** Focus on building buy-in from participating principals and teachers early.

- **Emphasize integration:** Emphasize interdisciplinary connections. Ensure that stakeholders understand the ways in which science, technology, engineering, and math are truly integrated, both conceptually and practically.
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- **Build community partnerships**: Engaging the community is very valuable and can lead to powerful relationships. Take the time to make those connections.
- **Involve the right people**: Make sure individuals in key positions have the right interest, attitude, and skills for the role.
- **Plan for the long-term**: Strategic, long-range planning is very important.

4) **All grant activities were “worth continuing”**

Finally, when asked what grant activities they would continue if they had unlimited resources, almost every grant coordinator indicated that they would not just continue, but expand every one of their grant activities. These expansion plans included:

- Increasing tours and field trips to STEM industries and institutes of higher education;
- Implementing science kits and labs across every science classroom;
- Expanding Project Lead the Way to every high school;
- Expanding STEM festivals;
- Providing more career guidance to students;
- Putting a science lab or a STEM lab in every school;
- Increasing science and math faculty enough to enable team teaching;
- Expanding industry partnerships;
- Implementing sustained professional development; and,
- Increasing access to technology.

**VII. Summative Findings**

**Characteristics of Successful STEM Programs**

The total evaluation results from Year One, Year Two, and Year Three reveal some characteristics of successful STEM education programs.

**In the Classrooms**

- Teachers use inquiry-based instruction and implement hands-on activities and project-based learning frequently.
- Teachers integrate content areas in their own work and collaborate across the curricula;
- Students engage with STEM professionals, professional STEM environments, and/or practical applications of STEM content.
- Teachers engage with STEM professionals, professional STEM environments, and/or practical applications of STEM content.
Teachers collaborate on instructional issues.

**In Program Operations**

- In-school resources for STEM education, both material and personnel, are available.
- A variety of courses in STEM subjects are available to students.
- Out-of-school resources for STEM education are available and accessible to students.
- A culture that values STEM education for all students exists.
- Program leaders build and maintain relationships with STEM industries and postsecondary education institutions.
- The program supports students from underrepresented groups.
- The program supports female students’ to develop confidence in engineering and technology.
- The program supports male students’ to be academically motivated.
- STEM professional development for teachers is hands-on, content-specific, grade-level specific, for particular skill-levels, and implements follow-up.
- Teachers have time away from students to develop instructional practices.
- Leaders conduct strategic, long-term planning and plan for sustainability.
- The right people are in the right roles.

**Considerations for Future Funding**

Evaluation findings also expose some operational areas in which funding efforts would be most likely to yield positive STEM education outcomes. These areas include resources for:

- **STEM education materials** – materials for hands-on investigations such as science kits, laboratory materials, and design equipment; science labs or STEM labs; hands-on curricula like Project Lead the Way; technological resources like laptops for students; or personnel resources for lab instruction or STEM instructional coaching.
- **Opportunities for students to engage with STEM industries** – tours of STEM industries or institutes of higher education; field trips; or student projects engaged with the community.
- **Opportunities for teachers to engage with STEM industries** – study trips; externships; specialized professional development; or fellowships.
- **Programs for underrepresented or underserved students** – special in-school or extracurricular activities aimed at female student confidence and interest in engineering and technology; in-school or extracurricular activities aimed at students who are visual and mechanical learners, struggle in school, or are English as second language learners.
- **Extracurricular STEM activities** – summer or track-out camps; after school clubs or competitions; in school clubs or competitions; or STEM festivals.
References


Contact Information:
Please direct all inquiries to Jeni Corn.
jocorn@ncsu.edu