Using STEM Case Studies to Prepare Today's Students for Tomorrow's Jobs

An Evaluation of Spark 101 Interactive STEM Videos

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Dr. Keller is an experienced researcher and evaluator in the areas of science and mathematics instruction. She has served as the Supervisor of Applied Research in the Montgomery County Public Schools; Associate Professor at the University of Maryland, College Park in the Department of Educational Measurement, Statistics, and Evaluation; and as the Director for Science Education Programs at The National Institute of Mental Health.

Dr. Keller is the author of numerous articles in publications such as *The Journal of Educational Research, The Journal of Research in Science Teaching,* and *The Journal of Educational Psychology.* She is the recipient of awards from The American Educational Research Association, The National Center for Education Statistics, and The International Testing and Evaluation Association, and she is an experienced presenter on issues related to STEM (science, technology, engineering, and mathematics) education and college readiness.

Contents

Executive Summary

This evaluation describes the effects of Spark 101 Interactive STEM Videos (Spark 101) on students' readiness for postsecondary STEM and STEM-related pathways. Results show that Spark 101 increased STEM understanding and interest among students with low prior STEM engagement, and that Spark 101 increased the STEM career awareness and skills of students with low and high prior STEM engagement. About four out of five Spark 101 participants recommended that teachers integrate more real-world problems into their classes and that employers provide more examples of career-based problem solving.

The Need for STEM-Capable Workers

Science, technology, engineering and mathematics (STEM) skills are the gateways to success in 21st century jobs, even jobs in non-STEM fields. The jobs of the future will require STEM-capable workers who can use technology, propose innovative approaches, devise creative solutions, and communicate ideas effectively. Unfortunately, the majority of high school graduates are unprepared for college-level STEM courses and the workplace.

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Building STEM Capability

High school STEM course pathways are key to helping students acquire the STEM knowledge and skills that underlie postsecondary success. Although the impact of any given course may be small, the cumulative impact of STEM coursework on students' overall levels of STEM engagement and preparedness can be large.

The instructional experiences that best prepare students for postsecondary success are those which offer opportunities for students to discern the difference between the body of knowledge in a given subject area and the processes by which that knowledge was developed. Inquiry-based learning experiences in high school STEM courses provide those opportunities and prepare students to meet the challenges of college and careers, regardless of their eventual field of study.

Using Case Studies to Improve STEM Capability

Case studies are one of the best ways to bring into the classroom the inquiry-based experiences that prepare students for postsecondary success. Case study experiences allow students to apply course content in a meaningful context. The experiences deepen students' understanding of what they are learning, strengthen their problem-solving skills, and make the subject matter easier to remember.

Case studies are one of the best ways to bring into the classroom the inquiry-based experiences that prepare students for postsecondary success.

Changes in technology have expanded the case study formats available to teachers. Spark 101 Interactive STEM Videos (Spark 101), a program developed by the 114th Partnership, uses an online interactive video format to present case studies guided by STEM professionals. Teachers can access free Spark 101 videos and curriculum-aligned teaching materials online at www.spark101.org.

Spark 101, a program developed by the 114th Partnership, uses an online interactive video format to present case studies guided by STEM professionals.

Spark 101 allows STEM teachers to choose from a collection of more than 50 case studies. The cases require students to think critically about real-world STEM problems that have no "right answer," to challenge alternative solutions, and to refine their conclusions as new data are collected. Each video also includes information about the STEM course and career pathways highlighted in that case.

Key Evaluation Findings

The results presented in this evaluation are drawn from a national sample of teachers whose students used Spark 101 in fall 2015. Pretest data were used to identify students who differed in their levels of overall STEM engagement prior to using Spark 101. Changes in STEM engagement and preparedness are presented for students with low versus high prior STEM engagement.

STEM Engagement

Spark 101 had statistically and practically significant effects on STEM engagement among students who, prior to using Spark 101, had little understanding of or interest in STEM pathways. After using Spark 101, students with low prior STEM engagement were significantly more likely to:

- Understand the relevance of their high school STEM courses.
- Be interested in STEM courses and careers.
- Increase their STEM coursetaking plans.

Spark 101 had statistically and practically significant effects on STEM engagement among students who, prior to using Spark 101, had little understanding of or interest in STEM pathways.

Students with high prior STEM engagement initially expressed keen understanding of the relevance of their STEM coursework and interest in STEM courses and careers. These students maintained their high levels of STEM understanding and interest after using Spark 101.

STEM Pathway Readiness

More than 70 percent of students with low prior STEM engagement reported that Spark 101 increased their awareness of STEM careers and how their STEM coursework relates to STEM careers. About 90 percent of students with high prior STEM engagement reported increases in their STEM career awareness.

About 80 percent of students with low prior STEM engagement reported that Spark 101 improved their STEM skills and their knowledge of how professionals draw upon those skills to solve STEM problems. About 90 percent of students with high prior STEM engagement reported improvements in their STEM skills and knowledge.

Students with low and high prior STEM engagement reported that Spark 101 increased their awareness of STEM careers and improved their STEM skills.

Instructional Effectiveness

Spark 101 can play a significant role in helping students prepare for STEM pathways. Although the case studies lasted only one or two class periods, results suggest that they had significant positive effects on STEM understanding of and interest in STEM courses and careers among students with low prior STEM engagement. Students with low and high prior STEM engagement reported that Spark 101 increased their awareness of STEM careers and improved their STEM skills.

Students' positive recommendations about the expanded use of Spark 101 provide further evidence of the role that STEM case studies can play in preparing today's students for tomorrow's jobs.

About 80 percent of students with low prior STEM engagement recommended that teachers integrate more real-world problems into their classes and that employers provide more examples of career-based problem solving. About 90 percent of students with high prior STEM engagement made the same recommendations. Students' positive recommendations about the expanded use of Spark 101 provide further evidence of the role that STEM case studies can play in preparing today's students for tomorrow's jobs.

Using STEM Case Studies to Prepare Today's Students for Tomorrow's Jobs: An Evaluation of Spark 101 Interactive STEM Videos

by Clare Keller, Ph.D.

This evaluation describes the effects of Spark 101 Interactive STEM Videos (Spark 101) on students' readiness for postsecondary STEM and STEM-related pathways. Results show that Spark 101 increased STEM understanding and interest among students with low prior STEM engagement, and that Spark 101 increased the STEM career awareness and skills of students with low and high prior STEM engagement. About four out of five Spark 101 participants recommended that teachers integrate more real-world problems into their classes and that employers provide more examples of career-based problem solving.

INTRODUCTION

A STEM-capable workforce is key to our nation's competitiveness in a global economy. Although the four STEM industries – science, technology, engineering, and mathematics – employ only five percent of the U.S. workforce, more than 70 percent of all U.S. jobs are STEM-related.[1] Yet the number of high school graduates who are STEM-capable lags far behind the number of projected job opportunities in STEM and STEM-related fields.

Although the four STEM industries – science, technology, engineering, and mathematics – employ only five percent of the U.S. workforce, more than 70 percent of all U.S. jobs are STEM-related.

In 2009, President Obama issued a call to action to improve STEM education, and for good reason. A large majority of high school students fail to reach proficiency on national mathematics and science assessments.[2] Our nation's high school graduates have weaker skills in literacy, mathematics, and problem-solving in technology-rich environments than their international peers.[3] Only about one in four high school graduates is prepared for the STEM college coursework needed for workplace success.[4]

The problem of student under-preparedness for STEM pathways is exacerbated by increases in the demand for STEM-capable workers in traditionally non-STEM industries.[5] The jobs of the future will require STEM-capable workers who can use technology, propose innovative approaches, devise creative solutions, and communicate ideas effectively. STEM skills are the gateways to success in 21st century jobs, even jobs in non-STEM fields.[6]

Only about one in four high school graduates is prepared for the STEM college coursework needed for workplace success.

The Changing Job Market

There is a growing gap in the range of career options available to high school students who are prepared for postsecondary education and those who are not.[7] This gap is due partly to a shift in the distribution of the types of jobs in the marketplace.[8] Over the past thirty years, the deployment of new technologies in the workplace has led to a sharp decline in the demand for middle-wage jobs that require routine, procedural skills.[9] Many of the blue collar and manual jobs that allowed high school graduates to earn a good living in the 1970s have since been automated or computerized.[10]

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By 2020, two thirds of all U.S. jobs will require at least some postsecondary education.[11] About one third of postsecondary education options include college. The other two thirds are a variety of options that include on the job training and employer-provided education programs.[12] Students' preparation for postsecondary education has significant consequences for their long-term earning power.[13,14]

Improvements in technology have led to rapid increases in the demand for highly educated workers, particularly those with a college degree.[15] On average, each additional year of postsecondary education raises an individual's annual income by 10 to 15 percent.[16,17,18] Even high school dropouts who are trained to use technology at work earn about 15 percent more than those who are not.[19]

In addition to higher wages in general, higher educational attainment is associated with a more rapid rate of wage increase. Between 1995 and 2005, the inflation-adjusted earnings of workers with four years of postsecondary education rose 12.5 percent, while the rate for high school graduates rose 5.8 percent.[20]

Among workers with similar incomes, those with higher educational attainment have jobs that are more rewarding and have greater prestige.[21] College graduates are almost twice as likely as high school graduates to receive formal training from their employers.[22] Employers find that the costs of additional training are lower when more educated persons are chosen for job-related training programs.[23]

Preparation for postsecondary education requires more than subject matter knowledge. Technological improvements that eliminated many of the blue collar jobs of the past also created jobs that did not exist a generation ago. Experts estimate that within 20 years nearly two thirds of workers will hold jobs that have not yet been created.

To be prepared for the jobs of the future, students need to develop the 21st century skills that allow them to adapt to unpredictable or novel circumstances and a changing work environment.[24,25] The best-prepared students will be those with critical thinking and problem-solving skills who are able to apply knowledge

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to solve a wide range of workplace challenges that, as of yet, are unforeseen.

Students' postsecondary preparation also has implications for their long-term job satisfaction and happiness.[26] Most individuals seek jobs that match their interests and abilities.[27,28,29] But they may have to change jobs several times before they find the best fit. Those who can apply what they have learned in the past to meet new sets of workplace challenges are most likely to be recruited for and obtain jobs that complement their ultimate career aspirations.

STEM Course Pathways

High school STEM course pathways can have life-long consequences for students' preparation for workplace success. Although the impact of any given course experience may be small, the cumulative effects of STEM course experiences are large. The 21st century skills that students learn in high school STEM courses prepare them to meet the challenges of college and careers, regardless of their field of study.

High school STEM course pathways can have life-long consequences for students' preparation for workplace success.

STEM coursetaking can yield significant economic returns when students enter the job market.[30,31.32,33] Students who take more STEM high school courses are more likely to pursue STEM college majors and careers.[34,35] STEM pathways lead to more high-paying jobs than do other course and career pathways.[36] Workers in STEM-related occupations earn more on average than their counterparts in other jobs, even when their educational attainment levels are the same.[37]

In addition to high-paying STEM occupations, STEM pathways open the doors to many other career opportunities. For example, about 20 percent of mathematics majors go on to work in the field of education. Even when workers with STEM degrees work in non-STEM occupations, they earn about 20 percent more than non-STEM majors working in the same jobs.[38]

21ST CENTURY STEM INSTRUCTION

One reason so many students are unprepared for postsecondary education is that they acquired their STEM knowledge and skills through high school instructional experiences that were designed for the 20th century. To prepare students for college and the workplace in the 21st century, STEM teachers need more flexibility in how they teach. One way to meet that need is through the use of case studies that connect classroom content to real-world experiences.

The majority of STEM instruction relies heavily on the use of textbooks and teacher-centered instruction. Textbooks and lectures are efficient teaching tools when teachers need to cover a large amount of content in a short amount of time. The problem with these methods is their inference that learning is about knowing the "right answers" and that facts and theories are certain. Rapid coverage of complex topics leads to acquisition of knowledge that is "a mile wide" and understanding that is "an inch deep."

To acquire the deep understanding that is the foundation of postsecondary readiness, students need instructional experiences that help them discern the difference between the knowledge in a given subject area and the processes by which that knowledge was developed. High-quality 21st century STEM education uses inquiry-based instructional approaches that allow student to bridge that gap.

To acquire the deep understanding that is the foundation of postsecondary readiness, students need instructional experiences that help them discern the difference between the knowledge in a given subject area and the processes by which that knowledge was developed.

Inquiry-based approaches require students to identify and pose solutions for real-world problems. The inquiry process develops better mastery of STEM course content and strengthens critical thinking skills that can be applied across the curriculum. As students begin to understand how information becomes knowledge, they can transfer what they learn in STEM classes to deepen their understanding of knowledge in other disciplines.[39]

Using Case Studies for STEM Instruction

Many instructional strategies have been implemented to enhance students' deep understanding. The most effective instructional strategies use inquiry-based methods to connect course content with real-world applications that demonstrate the relevance of what students learn in their classrooms. When students understand *why* they "need to know this," they are more engaged in their coursework and more likely to develop the skills and habits of mind that prepare them for postsecondary success.

The most effective instructional strategies use inquiry-based methods to connect course content with real-world applications that demonstrate the relevance of what students learn in their classrooms.

Case studies have been used as an inquiry-based instructional strategy in higher education for more than 150 years.[40] From the beginning, the use of case studies was driven by the belief that examination of actual events or situations could promote deep understanding of course content and prepare students for the real world of careers. The use of case studies has expanded beyond higher education to include audiences as diverse as precollege students and business leaders.

Although case studies are used for a variety of topics and purposes, all of them share a basic framework that requires students to analyze a problem or issue, find evidence to support alternative hypotheses or solutions, and communicate decisions or recommendations. The most effective case studies engage students with a provocative problem, provide for interaction, and contain high-quality visual material.[41]

The emphasis on critical thinking and decision making makes student-centered, case-based instruction more effective than traditional teacher-centered instruction that relies heavily on textbooks and lectures.

The emphasis on critical thinking and decision making makes student-centered, case-based instruction more effective than traditional teacher-centered instruction that relies heavily on textbooks and lectures.[42,43, 44] The case study process helps students learn to view issues from multiple perspectives and apply the skills they develop in one case to solve problems in another.[45]

Students report that case studies are more engaging than teacher-centered instructional methods and that the inquiry-based activities make course content easier to remember.

Case Studies and STEM Engagement

In addition to building STEM skills, case studies strengthen students' STEM engagement. Students report that case studies are more engaging than teacher-centered instructional methods and that the inquiry-based activities make course content easier to remember.[46,47]

Instruction that enhances STEM engagement can have a significant effect on students' postsecondary choices and job satisfaction.[48,49] STEM engagement has a greater influence on students' decisions to pursue postsecondary STEM studies and careers than factors such as academic achievement and prior experience.[50,51,52,53]

Students with higher levels of STEM engagement understand the relevance of STEM for their daily lives and are more interested in STEM coursework and careers. STEM engagement can have lifelong benefits. Individuals who pursue STEM majors in college report some of the highest ratings of job satisfaction later in life, regardless of the career path they followed after graduation.[54]

Spark 101 Interactive STEM Videos (Spark 101) provide opportunities for students to connect their STEM coursework experiences with the real-world challenges faced by STEM professionals.

Spark 101 Interactive STEM Videos

Spark 101 Interactive STEM Videos (Spark 101) provide opportunities for students to connect their STEM coursework experiences with the real-world challenges faced by STEM professionals. Participation in Spark 101 case studies deepens students' understanding of how the knowledge they acquire in the classroom can be applied in the workplace and introduces them to a range of STEM and STEM-related professional pathways.

The 114th Partnership developed Spark 101 to foster students' understanding of the classroom-workplace connection and strengthen their professional pathway readiness.

The Classroom-Workplace Connection

Named for the meridian that bridges the Great Continental Divide, the 114th Partnership is a national nonprofit whose core mission is to bridge the divide between the ways knowledge and skills are taught in the classroom and the ways they are applied in the workplace. The 114th Partnership developed Spark 101 to foster students' understanding of the classroom-workplace connection and strengthen their professional pathway readiness.

The 114th Partnership uses the term *professional pathway readiness* to express the concept of students' readiness for ongoing postsecondary education in a changing global economy. The jobs of the future will require individuals to develop new skills throughout their careers. When students understand the link between the classroom and the workplace, they are better able to connect their personal talents and interests to their professional pathway choices and are more likely to want to further develop their skills via new and traditional postsecondary education options.

Spark 101 includes more than 50 case studies on a variety of STEM topics, each of which is linked directly to specific curriculum standards in the relevant STEM subject area.

Spark 101 Instructional Materials

The best case studies include materials that streamline teachers' instructional planning and are matched to specific course objectives.[55] Spark 101 includes more than 50 case studies on a variety of STEM topics, each of which is linked directly to specific curriculum standards in the relevant STEM subject area. Rather than being an "add-on" to an already full curriculum, the Spark 101 case studies were designed to support the existing curriculum.

From a teacher's perspective, the benefits of using case studies can be outweighed by the cost of time needed to conduct them. The limited instructional time available to cover course content is especially problematic for STEM teachers who need to prepare students for more advanced courses, or standardized tests, or both. All the Spark 101 case studies follow the same format and can be completed within one or two class periods.

The amount of preparation time needed to plan and execute high-quality inquiry-based instruction can be burdensome even for the most experienced teachers.[56] Every Spark 101 case study includes course topic guides and lesson plans that can be used to prepare students for the case they are about to investigate and help teachers facilitate student inquiry. The instructional resources minimize the amount of time teachers need to plan and present the case studies.

Spark 101 cases provide opportunities for students to model the behavior of STEM professionals as they attempt to solve problems that have no "right answer."

Spark 101 Case Study Format

Spark 101 case studies provide opportunities for students to model the behavior of STEM professionals as they attempt to solve problems that have no "right answer." The case studies encourage students to think critically, challenge assumptions, and refine solutions in light of new information and insights. Teachers can access free Spark 101 videos and curriculum-aligned teaching materials online at www.spark101.org.

Every Spark 101 case study is divided into three segments— the problem, the solution, and the pathway. The first segment, the problem, engages students in a scenario that demonstrates the relevance of STEM coursework and careers in their daily lives. The solution segment builds their STEM skills, increases their understanding of how those skills are used by STEM professionals, and helps students discern how well the profiled careers match their personal interests.

And the third segment, the pathway, presents information to increase students’ STEM awareness and inform their coursetaking plans.

Spark 101 uses an interrupted case study presentation method. This method is a favorite case approach with teachers because it shows how STEM knowledge is revised and developed as more complete data become available.[57]

A typical Spark 101 case study begins when an industry professional introduces students to a real-world problem taken from his or her organization. Teachers then pause (interrupt) the video to give groups of students time to come up with tentative solutions. After students work on solutions, they watch the second video segment.

A typical Spark 101 case study begins when an industry professional introduces students to a real-world problem taken from his or her organization. Teachers then pause (interrupt) the video to give groups of students time to come up with tentative solutions.

During the second segment, the industry professional provides some additional information, explains how his or her organization arrived at its solution, and asks students to compare their processes and recommendations with those presented in the case. After some discussion, students watch a third segment which provides information about the profiled careers, the educational requirements of those careers, and personal advice from the industry professional about how to learn more about that career pathway.

Evaluation Purpose

Formative evaluation data collected during Spark 101 development suggested that the interactive case studies enhanced students' understanding of the classroom-workplace connection and motivated them to want to learn more about STEM courses and careers. The purpose of this summative evaluation was to examine the effects of Spark 101 on changes in students' STEM engagement and pathway readiness.

METHODOLOGY

One of the potential benefits of Spark 101 participation is the effect on STEM engagement. This evaluation examined whether students with low prior STEM engagement were newly inspired to learn more about STEM courses and careers, and whether students with high prior STEM engagement remained highly committed to STEM pathways.

Another potential benefit of Spark 101 participation is the effect on STEM pathway readiness. The analysis examined whether Spark 101 participation increased the STEM awareness and skills of students with low and high prior levels of STEM engagement.

This evaluation examined whether students with low prior STEM engagement were newly inspired to learn more about STEM courses and careers, and whether students with high prior STEM engagement remained highly committed to STEM pathways.

RESEARCH QUESTIONS

The answers to each of the following six research questions compared results for students with low versus high levels of STEM engagement prior to their participation in Spark 101.

1. Does Spark 101 help students better understand the relevance of STEM courses for their lives?
2. Does Spark 101 increase students' interest in STEM courses and careers?
3. Does Spark 101 influence students' STEM high school coursetaking plans?
4. Does Spark 101 increase students' awareness and understanding of STEM careers and how the knowledge acquired in their STEM courses relates to STEM careers?
5. Does Spark 101 increase students' STEM skills and their understanding of how those skills are used by STEM professionals?

6. Is the Spark 101 case study approach an effective instructional tool for students with different levels of STEM engagement?

Analytic Model

This evaluation used a repeated measures design with a comparison group to measure the effects of Spark 101 case studies on students' STEM engagement and preparedness.

Intervention

Teachers administered pretests to their students prior to presenting Spark 101. Within a few days of the pretest, teachers presented a Spark 101 case study that was related to their particular STEM course content. Teachers completed the case studies in one or two class periods. Within a few days after the case studies were completed, teachers administered posttests.

This evaluation used a repeated measures design with a comparison group to measure the effects of Spark 101 on students' STEM engagement and preparedness.

Analytic Sample

The results reported in this document are drawn from a population of 919 middle and high school students who participated in Spark 101 in fall 2015. Spark 101 participants were enrolled in middle and high school STEM classes taught by a national sample of 17 teachers. The majority of students were members of groups that traditionally are underrepresented in STEM pathways (i.e., African American and Hispanic students).

The analytic sample included 431 students with matched Spark 101 pretest and posttest responses. Results are excluded for 488 students who took the pretest only or were missing the identifying data needed to match their pretest and posttest responses.

Instrumentation

The pretest and posttest Likert scale items were measured on a scale of 1 (Strongly Disagree) to 4 (Strongly Agree). The pretest items measured students' STEM understanding, interest, and coursetaking plans. The posttest included the pretest items plus items that measured changes in students' STEM awareness and skills and their satisfaction with Spark 101.

Both instruments included items that requested identifying information that allowed individual students' pretest and posttest responses to be matched. The items used to match students were teacher name, course name, class period, a student identification number assigned by the teacher, gender, and grade level.

A factor analysis was used to create STEM engagement scores based on students' overall responses to all pretest items. The Cronbach's alpha reliability for the full pretest scale was 0.83. The STEM engagement factor had a mean of zero and a standard deviation of one. Students with factor scores of zero or less were assigned to the low engagement group. Students with factor scores greater than zero were assigned to the high engagement group.

A factor analysis was used to create STEM engagement scores based on students' overall responses to all pretest items.

Statistical Analysis

The students who participated in Spark 101 were enrolled in a wide range of grade levels and courses. Students enrolled in classes with the same teacher are more likely to be similar to each other than to students enrolled in classes with different teachers. When there are significant between-teacher differences, multilevel models are a better choice than unilevel models for comparing program outcomes.

Preliminary ANOVA tests were conducted to determine whether multilevel models should be used for this evaluation. There were no significant between-teacher differences in the mean prior STEM engagement scores of all students included in the analytic sample. Additional ANOVA comparisons for students with different levels of STEM engagement revealed no significant between-group differences in outcomes for students assigned to different teachers.

Analyses were conducted separately for students with low and high levels of prior STEM engagement.

Because there was no significant between-teacher variability, this evaluation used a series of unilevel models. Analyses were conducted separately for students with low and high levels of prior STEM engagement. The results are reported in terms of their statistical and practical significance.

Measures of statistical significance are reported as *p*-values. The smaller a *p*-value, the smaller the likelihood that an observed difference is due to chance. Because calculations of *p*-values take group sizes into account, a given difference may be statistically significant ($p < 0.05$) when group sizes are large, but not statistically significant when group sizes are small.

The results reported for items included on the pretest summarize mean differences in students' pretest and posttest responses.

Measures of practical significance are reported as effect sizes. Effect sizes (ES) are standardized measures of the policy-relevant and practical significance of mean differences. ES calculations are not sensitive to group size and may detect program effects that are practically significant even when *p*-values are not statistically significant. ES values of 0.1, 0.2, 0.5, and 0.8 represent very small, small, medium, and large effects, respectively.

The results reported for items included on the pretest summarize mean differences in students' pretest and posttest responses. One sample t-tests were used to measure the statistical significance of mean pretest-posttest differences. The effect sizes were calculated from the mean differences divided by the standard deviations (SD) of the differences.

The results reported for items included only on the posttest show the percentages of students who expressed positive responses to questions about the effects of Spark 101. One sample t-tests were used to measure the significance of the students' posttest mean scores versus the posttest scale mean score of 2.5 (neutral response).The effect sizes are calculated from the difference of the students' mean score versus the posttest mean score divided by the posttest SD.

The results reported for items included only on the posttest show the percentages of students who expressed positive responses to questions about the effect of Spark 101.

Control for Potential Limitations

In any evaluation, limitations of the evaluation design can threaten the validity of the findings. These limitations can introduce alternative explanations for differences that otherwise are attributed to program effects and raise questions about the extent to which the evaluation results can be generalized across the population of interest. Analysis of the limitations of this evaluation design found no evidence of three potential threats to validity.

Experimental Mortality

Experimental mortality occurs when there is a loss of subjects during the data collection process. The loss of subjects is a potential threat to validity when subjects non-randomly drop out (are excluded from the analytic sample) or the remaining analytic sample is not representative of the evaluation population.

There were no significant differences in the gender or mean prior STEM engagement scores of students who were included in the analytic sample and those who were excluded.

In this evaluation, more than 50 percent of students who took the pretest were excluded from the analytic sample because they did not have matched posttest data. Statistical analyses were conducted to compare the characteristics of the analytic sample with the pretest population. There were no significant differences in the gender or mean prior STEM engagement scores of students who were included in the analytic sample and those who were excluded. The analytic sample was representative of the evaluation population (Appendix A).

Statistical Regression

Regression to the mean did not occur for students with extreme scores.

Statistical regression to the mean is common when the first measure of a variable (pretest) is extremely high or low. In general, subjects with extreme pretest scores tend to score closer to average (regress toward the mean) on the posttest. This phenomenon can threaten validity if the analysis ignores the potential bias introduced by extreme scores.

Post hoc analysis examined whether improvements among students with the lowest pretest scores were offset by posttest declines among students with highest pretest scores. Regression to the mean did not occur for students with extreme scores. Although the pretest-posttest differences for students with low pretest scores showed improvement, the differences for students with high pretest scores showed no change.

Although the participants were not randomly selected, they included a national cross-section of middle and high school STEM teachers and a diverse student population.

Selection

Although the participants were not randomly selected, they included a national cross-section of middle and high school STEM teachers and a diverse student population. Post hoc analysis of the overall trends in STEM engagement and postsecondary readiness found that the outcomes observed for this analytic sample were consistent with those observed for different samples of students and teachers who participated in Spark 101 formative evaluations in 2013 and 2014.

RESULTS

The results are organized in two sections. The first summarizes pretest-posttest mean differences in STEM engagement. The second summarizes posttest responses that measure the effects of Spark 101 instruction on students' STEM pathway readiness.

STEM ENGAGEMENT

The results for this section summarize the significance of pretest and posttest differences in students' perceptions of their understanding of the relevance of STEM courses in their daily lives, their interest in STEM courses and careers, and their high school coursetaking plans. Additional data are provided in Appendix A.

Spark 101 participation helped students with low prior STEM engagement better understand the relevance of their STEM courses.

The Relevance of STEM Coursework

Spark 101 participation helped students with low prior STEM engagement better understand the relevance of their STEM courses (Table 1). The increases in STEM understanding among students with low prior STEM engagement were practically and statistically significant.

Table 1
Effect of Spark 101 on STEM Understanding by
Prior STEM Engagement Level

STEM Understanding	Low STEM Engagement		High STEM Engagement	
I understand	Mean Difference[a]	ES	Mean Difference[a]	ES
how what I learn in STEM courses relates to my life.	0.2	0.32*	-0.0	-0.03

[a] Mean difference of posttest minus pretest scores.
* Statistically significant ($p < 0.05$).

Students with high prior levels of STEM engagement were likely already to understand how what they learn in STEM courses relates to their lives (Appendix A). The changes in their STEM understanding were not practically or statistically significant (Table 1).

Spark 101 participation had a significant effect on interest in STEM courses and careers among students with low prior STEM engagement.

Interest in STEM Courses and Careers

Spark 101 participation had a significant effect on interest in STEM courses and careers among students with low prior STEM engagement (Table 2). After using Spark 101, this group reported greater interest in taking more STEM courses and in careers that use what they learn in their STEM courses. The improvements in STEM interest among students with low prior STEM engagement were practically and statistically significant.

Students with high prior levels of STEM engagement maintained their keen interest in STEM courses and careers (Appendix A). The changes in their STEM interest were not practically or statistically significant (Table 2).

Table 2
Effect of Spark 101 on STEM Interest by Prior STEM Engagement Level

STEM Interest	Low STEM Engagement		High STEM Engagement	
I am interested in	Mean Difference[a]	ES	Mean Difference[a]	ES
taking more STEM courses.	0.2	0.23*	-0.0	-0.01
a career that uses what I learn in my STEM courses.	0.2	0.27*	-0.1	-0.05

[a] Mean difference of posttest minus pretest scores.
* Statistically significant ($p < 0.05$).

STEM Coursetaking Plans

Spark 101 participation had a significant effect on the STEM coursetaking plans of students with low prior STEM engagement (Table 3). After using Spark 101, this group of students was significantly more likely to report that they planned to take four years of mathematics and four years of science by the end of high school. In addition, this group was significantly more likely to report that they planned to take computer science, statistics, and technology education courses by the end of high school. The increases in STEM coursetaking plans were practically and statistically significant.

Spark 101 participation had a significant effect on the STEM coursetaking plans of students with low prior STEM engagement.

Students with high prior STEM engagement maintained their already high levels of commitment to take four years of mathematics and four years of science by the end of high school (Appendix A). In addition, this group remained highly committed to taking computer science, statistics, and technology education courses by the end of high school. The changes in their STEM coursetaking plans were not practically or statistically significant (Table 3).

Table 3
Effect of Spark 101 on STEM High School Coursetaking Plans by Prior STEM Engagement Level

STEM Coursetaking Plans	Low STEM Engagement		High STEM Engagement	
By the end of high school I plan to take	Mean Difference[a]	ES	Mean Difference[a]	ES
4 years of mathematics	0.2	0.24*	0.0	0.04
4 years of science	0.2	0.16*	-0.0	-0.01
a computer science course	0.2	0.21*	-0.0	-0.05
a statistics course	0.1	0.16*	0.1	0.09
a career and technology course	0.2	0.18*	-0.0	-0.07

[a] Mean difference of posttest minus pretest scores.
* Statistically significant ($p < 0.05$).

STEM Pathway Readiness

This section summarizes the significance of students' posttest responses to questions about the effect of Spark 101 on their pathway readiness. Additional data are provided in Appendix A.

STEM Awareness

Spark 101 case studies offer students opportunities to interact virtually with STEM professionals and to make connections between their STEM coursework and STEM-based careers. Student posttest results suggest that Spark 101 increased their STEM awareness.

More than 70 percent of students with low prior STEM engagement reported that Spark 101 increased their awareness of STEM careers and how their coursework relates to STEM careers (Table 4). Nearly 90 percent of students with high prior STEM engagement reported the same findings (Table 4).

The reported increases in the effect of Spark 101 on STEM awareness were practically and statistically significant for students with both low and high prior STEM engagement.

More than 70 percent of students with low prior STEM engagement reported that Spark 101 increased their awareness of STEM careers and how what they are learning relates to STEM careers.

Table 4
Effect of Spark 101 on Students' STEM Awareness by Prior STEM Engagement Level

STEM Awareness	Low STEM Engagement		High STEM Engagement	
Spark 101 helped me increase my awareness of	% Reported Increased Awareness	ES[a]	% Reported Increased Awareness	ES[a]
STEM careers.	70.4	0.30*	87.7	0.71*
how what I am learning relates to STEM careers.	77.6	0.39*	89.4	0.77*

[a] ES based on group posttest mean score compared with posttest scale mean of 2.5.
* Statistically significant ($p < 0.05$).

STEM Skills

Spark 101 case studies present workplace challenges that require students to apply what they learn in their STEM courses to solve problems faced by STEM professionals. Student posttest results suggest that Spark 101 increased their STEM skills.

About 80 percent of students with low prior STEM engagement reported that Spark 101 improved their STEM skills and their understanding of how professionals draw upon those skills to solve STEM problems (Table 5). About 90 percent of students with high prior STEM engagement reported the same findings.

The reported increases in the effect of Spark 101 on students' STEM skills were practically and statistically significant for students with both low and high prior STEM engagement.

About 80 percent of students with low prior STEM engagement reported that Spark 101 improved their STEM skills and their understanding of how professionals draw upon those skills to solve STEM problems.

Table 5
Effect of Spark 101 on STEM Skills by
Prior STEM Engagement Level

STEM Skills	Low STEM Engagement		High STEM Engagement	
Spark 101 helped me	% Reported Increased Skills	ES[a]	% Reported Increased Skills	ES[a]
improve my skills at solving real-world problems.	78.3	0.45*	87.6	0.78*
understand how STEM skills are used to solve real-world problems.	81.5	0.46*	88.8	0.79*

[a] ES based on group posttest mean score compared with posttest scale mean of 2.5.
* Statistically significant ($p < 0.05$).

Instructional Effectiveness

Spark 101 case studies offer students opportunities to work together to solve problems that make classroom instruction more relevant to their daily lives. Student posttest results suggest that inquiry-based Spark 101 activities are an engaging and effective method of STEM instruction.

About 80 percent of students with low prior STEM engagement recommended that teachers integrate more real-world problem solving in their classes and that employers provide more examples of career-based problem solving (Table 6). About 90 percent of students with high prior STEM engagement made the same recommendations.

The students' positive recommendations about the use and availability of Spark 101 were practically and statistically significant for students with both low and high prior STEM engagement.

About 80 percent of students with low prior STEM engagement recommended that teachers integrate more real-world problems into their classes and that employers provide more examples of career-based problem solving.

Table 6
Students' Recommendations for Spark 101 by
Prior STEM Engagement Level

Students' Recommendations	Low STEM Engagement		High STEM Engagement	
I recommend	% Recommend	ES[a]	% Recommend	ES[a]
my teachers integrate more real-world problem solving in my classes.	80.4	0.41*	87.6	0.76*
employers provide more examples of career-based problem solving.	77.9	0.38*	88.8	0.73*

[a] ES based on group posttest mean score compared with posttest scale mean of 2.5.
* Statistically significant ($p < 0.05$).

Discussion

Students need to complete postsecondary STEM courses to be competitive in the workplace. Nearly three out of every four U.S. jobs are STEM-related. The trends in the job market suggest that the demand for workers with STEM skills will rise. Between 2008 and 2018, the number of STEM-related jobs is expected to grow at twice the rate of non-STEM jobs.[58]

The 21st century skills that students learn in high school STEM courses prepare them to meet the challenges of college and careers, regardless of their field of study. Unfortunately, the supply of high school graduates who have mastered those skills has not kept pace with growing workforce needs.

The 21st century skills that students learn in high school STEM courses prepare them to meet the challenges of college and careers, regardless of their field of study.

Most students acquire STEM pathway preparation through high school coursework that tends to emphasize discrete facts with a focus on breadth over depth. Few students develop deep understanding of how the knowledge they acquire in their courses connects to the actual work that STEM professionals perform. Spark 101 provides high-quality inquiry-based STEM instruction that can help to bridge the learning gap between the classroom and the workplace.

Greater understanding of the relevance of STEM can broaden students' perceptions of how STEM courses and careers can be aligned with their interests, abilities, and goals. Student interest in STEM courses and careers can be strengthened further by virtual interactions with STEM professionals in the case study videos. Spark 101 introduces students to careers that may be unknown to them or their teachers. Professionals who made nontraditional career choices can serve as role models who help students "see themselves" in STEM careers.

Spark 101 introduces students to careers that may be unknown to them or their teachers.

STEM Engagement

Spark 101 had the greatest effect on STEM understanding, interest, and coursetaking plans among students who reported low levels of prior STEM engagement. Students with low levels of STEM engagement reported significant increases in their understanding of how their STEM coursework relates to their lives.

Spark 101 had the greatest effect on STEM understanding, interest, and coursetaking plans among students who reported low levels of prior STEM engagement.

Results suggest that greater understanding of the relevance of STEM coursework contributed to increased interest in STEM. After using Spark 101, students with low prior STEM engagement reported significantly increased interest in STEM courses and careers and commitment to their STEM coursetaking plans.

STEM Pathway Readiness

Often, students' postsecondary preparation is limited by their lack of awareness of how the knowledge they acquire in the classroom connects with real-world tasks performed in the workplace. Students who participated in Spark 101 reported greater awareness of STEM careers and how the skills they learn in their courses are applied by STEM professionals.

Students who participated in Spark 101 reported greater awareness of STEM careers and how the skills they learn in their courses are applied by STEM professionals.

Most high school coursework tends to emphasize discrete facts with a focus on breadth over depth. Spark 101 case studies allow students to expand their focus and use what they learn in the classroom to solve real-world problems. Students reported that Spark 101 increased their STEM skills and gave them new insight into how STEM professionals use those skills.

Instructional Effectiveness

Spark 101 can play a significant role in helping students prepare for STEM pathways. Although the case studies lasted only one or two class periods, results suggest that they had significant positive effects on STEM understanding of and interest in STEM courses and careers among students with low prior STEM engagement. Students with low and high prior STEM engagement reported that Spark 101 participation increased their awareness of STEM careers and improved their STEM skills.

About four out of five students recommended that teachers and employers provide more opportunities to use and access case studies like those presented in Spark 101. Students' positive recommendations about the expanded use of Spark 101 provide further evidence of the role that STEM case studies can play in preparing today's students for tomorrow's jobs.

About four out of five students recommended that teachers and employers provide more opportunities to use and access case studies like those presented in Spark 101.

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Appendix A

Table A1
Comparison of All Pretest Takers and Analytic Sample Included in the Evaluation of Spark 101 Interactive STEM Videos

	All Pretest Takers		Analytic Sample	
Characteristic	*N*	%	*N*	%
All	919		431	
Gender				
Male	433	47.1	203	47.1
Female	486	52.9	228	52.9
Prior STEM Engagement				
Low	412	50.1	205	52.2
High	411	49.9	188	47.8
Prior STEM Engagement by Gender				
Low	412		205	
Male	185	44.9	93	45.4
Female	227	55.1	112	54.6
High	411		188	
Male	201	48.9	91	48.4
Female	210	51.1	97	51.6

Table A2
Effect of Spark 101 Interactive STEM Videos on Students' STEM Understanding
by Prior Stem Engagement Level

STEM Understanding	*N*	Pretest Mean[a]	Posttest Mean[a]	Mean Diff[b]	ES
Low Prior STEM Engagement					
I understand how what I learn in STEM courses relates to my life.	204	2.7	2.9	0.2	0.32*
High Prior STEM Engagement					
I understand how what I learn in STEM courses relates to my life.	188	3.5	3.5	-0.0	-0.03

[a] Mean score on a scale of 1 to 4.
[b] Mean difference of posttest minus pretest scores.
* Statistically significant difference ($p < 0.05$).

Table A3
Effect of Spark 101 Interactive STEM Videos on Students' STEM Interest
by Prior Stem Engagement Level

STEM Interest	*N*	Pretest Mean[a]	Posttest Mean[a]	Mean Diff[b]	ES
Low Prior STEM Engagement					
I am interested in taking more STEM courses.	205	2.4	2.6	0.2	0.23*
I am interested in a career that uses what I learn in my STEM courses.	205	2.4	2.6	0.2	0.27*
High Prior STEM Engagement					
I am interested in taking more STEM courses.	188	3.3	3.3	-0.0	-0.01
I am interested in a career that uses what I learn in my STEM courses.	186	3.3	3.2	-0.1	-0.05

[a] Mean score on a scale of 1 to 4.
[b] Mean difference of posttest minus pretest scores.
* Statistically significant difference ($p < 0.05$).

Table A4
Effect of Spark 101 Interactive STEM Videos
on Students' STEM High School Coursetaking Plans
by Prior Stem Engagement Level

STEM High School Coursetaking Plans	*N*	Pretest Mean[a]	Posttest Mean[a]	Mean Diff[b]	ES
Low Prior STEM Engagement					
By the end of high school I plan to take					
4 years of mathematics	202	2.9	3.1	0.2	0.24*
4 years of science	201	2.8	3.0	0.2	0.16*
a computer science course	199	2.5	2.7	0.2	0.21*
a statistics course	199	2.3	2.4	0.1	0.16*
a career and technology course	204	2.5	2.7	0.2	0.18*
High Prior STEM Engagement					
By the end of high school I plan to take					
4 years of mathematics	187	3.7	3.7	0.0	0.04
4 years of science	187	3.7	3.7	-0.0	-0.01
a computer science course	187	3.3	3.3	-0.0	-0.05
a statistics course	180	3.0	3.1	0.1	0.09
a career and technology course	186	3.3	3.3	-0.0	-0.07

[a] Mean score on a scale of 1 to 4.
[b] Mean difference of posttest minus pretest scores.
* Statistically significant difference ($p < 0.05$).

Table A5
Effect of Spark 101 Interactive STEM Videos on Students' STEM Awareness
by Prior Stem Engagement Level

STEM Awareness	*N*	Posttest Mean[a]	ES[b]	% Increased Awareness
Low Prior STEM Engagement				
Spark 101 helped me increase my awareness of				
STEM careers.	203	2.8	0.30*	70.4
how what I am learning relates to STEM careers.	205	2.9	0.39*	77.6
High Prior STEM Engagement				
Spark 101 helped me increase my awareness of				
STEM careers.	187	3.2	0.71*	87.7
how what I am learning relates to STEM careers.	188	3.3	0.77*	89.4

[a] Mean score on a scale of 1 to 4.
[b] ES based on group posttest mean score compared with posttest scale mean of 2.5.
* Statistically significant ($p < 0.05$).

Table A6
Effect of Spark 101 Interactive STEM Videos on Students' STEM Skills
by Prior Stem Engagement Level

STEM Skills	*N*	Posttest Mean[a]	ES[b]	% Increased Skills
Low Prior STEM Engagement				
Spark 101 helped me				
improve my skills at solving real-world problems.	203	3.0	0.45*	78.3
understand how STEM skills are used to solve real-world problems.	205	3.0	0.46*	81.5
High Prior STEM Engagement				
Spark 101 helped me				
improve my skills at solving real-world problems.	186	3.3	0.78*	87.6
understand how STEM skills are used to solve real-world problems.	188	3.3	0.79*	88.8

[a] Mean score on a scale of 1 to 4.
[b] ES based on group posttest mean score compared with posttest scale mean of 2.5.
* Statistically significant ($p < 0.05$).

Table A7
Students' Recommendations for Spark 101 Interactive STEM Videos
by Prior Stem Engagement Level

Students' Recommendations	*N*	Posttest Mean[a]	ES[b]	% Recommend
Low Prior STEM Engagement				
I recommend				
my teachers integrate more real-world problem solving in my classes.	204	2.9	0.41*	80.4
employers provide more examples of career-based problem solving.	204	2.9	0.38*	77.9
High Prior STEM Engagement				
I recommend				
my teachers integrate more real-world problem solving in my classes.	188	3.3	0.76*	91.5
employers provide more examples of career-based problem solving.	188	3.2	0.73*	90.4

[a] Mean score on a scale of 1 to 4.
[b] ES based on group posttest mean score compared with posttest scale mean of 2.5.
* Statistically significant ($p < 0.05$).

The 114th Partnership®

Spark 101® is a program of the 114th Partnership, a national nonprofit that facilitates productive partnerships between educators and employers.

Our collaborations support ongoing relationships and measurable outcomes. Since 2013, we have reached approximately 2,000 educators and 500,000 students.

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For more information on Spark 101 Interactive STEM Videos, email professionalpathways@114th.org.
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