University Science Partnerships: What Happens to STEM Interest and Confidence in Middle School and Beyond

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Abstract

Increased demand for qualified students interested in science, technology, engineering, and mathematics (STEM) has created a push for greater and more authentic exposure to STEM topics among K-12 students. University science partnerships have been shown to be effective at increasing high school students' interest and confidence in STEM fields. However, little research to date has explored the effects of these partnerships on students beyond the initial program. This study explored STEM interest and confidence in 322 middle school students involved in a GK-12 program before and immediately after the program, then followed up with the students again in high school. Results indicated that students experienced slight losses in areas of STEM interest and confidence during the program, but greater, significant losses occurred after middle school. Male and female students, however, demonstrated a narrowing STEM aspiration gender gap by high school. Implications for university partnership programs are discussed.

For more than a decade, educators, scholars, and policymakers have emphasized the need to promote students' interests and confidence in science, technology, engineering, and mathematics (STEM) fields. Additional emphases have focused on increasing the number of students intending to major in, or explore career options in, a STEM-related field. Increasing a students' STEM interests and intents could benefit the students on a personal level, by improving their job prospects, but also has broader social benefits, such as strengthening the United States' position to be globally competitive. Strategic partnerships between K-12 schools and institutions of higher education provide a pathway to promote students' learning and development in STEM. The National Science Foundation's Graduate Teaching Fellows in K-12 Education (GK-12) Program created a pathway to promote partnerships between K-12 and four-year colleges and universities. GK-12 aimed to "connect elementary and secondary learning to the habits and skills required for future study in STEM disciplines [and] provide role models for future STEM professionals" (Mitchell et al., 2003, p. 4), but was GK-12 successful in generating student's STEM interest and confidence?

This study looked at a partnership between a university and middle school and the influence of the partnership on students' STEM interest and confidence. We tested whether the presence of a resident scientist in a middle school classroom had an effect on students during the middle school partnership year, and whether those effects were maintained later in high school. In the following sections, we first review extant literature and synthesize what is already known. We briefly describe literature on K-12 students' confidence and interest in STEM careers, describe our data collection and analytic approach, and conclude with a discussion of the results and implications.

Background

Confidence and Interests in STEM

Increasing the STEM workforce has been a national priority throughout the previous decade (Banning & Folkestad, 2012). Although the number of students in STEM fields has increased steadily during that time, demand for qualified STEM professionals continues to rise, and women and those of ethnic and racial minorities are disproportionately underrepresented in STEM undergraduate programs (National Science Board, 2016). A concern for policymakers should be to promote programming that fosters STEM interests in the pre-college years, when young students form their beliefs, interests, and confidence in potential careers. Research has shown that engaging and authentic STEM-based programs in middle and high school encourage students' STEM interest and STEM career aspirations (Christensen, Knezek, & Tyler-Wood, 2015). Research suggests that K-12 and university partnership programs may develop students' STEM interest and confidence, though few studies examine these partnerships and whether student gains are maintained when the programs end.

High school students' STEM aspirations (i.e., interests and confidence) are a strong predictor of their future college program choices and university graduation rates (Fouad & Smith, 1996; Legewie & DiPrete, 2012). STEM confidence, or the ability to feel like one can be successful in STEM courses and careers, plays an important role in students' career aspirations (Ferry, Fouad, & Smith, 2000). However, these aspirations develop even earlier than the secondary level. Sadler, Sonnert, Hazari, and Tai (2012) found that STEM career interest developed during high school, and declined during that time for females. Sadler and colleagues believed STEM interest must be nurtured prior to high school to address the disparity of interests that exists among genders. Buldu (2006) found that career interest begins at the elementary school level, and others have found that the gap in STEM interest between genders also emerges at this time (Régner et al., 2015). It is not clear when, exactly, STEM interests formally develop, but clearly, it must be nurtured prior to high school.

Partnership Programs

University and K-12 STEM partnerships have gained popularity as a way to engage students, teachers, and graduate student scientists in the process of scientific inquiry. Resulting from the federal government's STEM educational focus in recent years, funding for university and K-12 partnerships increased over the same period. These partnerships benefit K-12 school districts for two reasons. First, the Next Generation Science Standards (American K-12 science standards) emphasize authentic and conceptual science practices. Teachers may not have the pedagogical knowledge to integrate these standards meaningfully into practice, whereas partnership programs may provide them necessary professional development to do so (Breiner, Harkness, Johnson, & Koehler, 2012). Next, because science interest may be predicted by exposure of scientific content (National Science Board, 2016), university collaboration has become an effective way of providing such exposure to K-12 students.

In a notable study, Gibson and Chase (2002) performed longitudinal research on students who were involved in a science-based, middle school summer camp. When the students were later surveyed in high school, Gibson and Chase found those who were involved in the program had maintained more positive attitudes of and higher interest in science careers. They recommended that further studies should identify other variables that influence students' interests and attitudes between the two time points. More recent follow-up research has confirmed these results about summer science camps (Kong, Dabney, & Tai, 2014) and out-of- school science-based activities, or informal science learning (Dabney

et al., 2012). Others have concluded that even brief middle school student-scientist interactions aide in students' understanding of science careers (Woods-Townsend et al., 2015), suggesting that GK-12 experiences in middle school may have a similar effect.

Evidence suggests that students' interests in STEM career choices are strongly, positively affected by attitudes and confidence (Riegle-Crumb, Moore & Ramos-Wada, 2011). Thus, "to attract students into the sciences and engineering, we should pay close attention to children's early exposure to science at the middle and even younger grades" (Tai, Liu, Maltese, & Fan, 2006, p.1144). Additionally, it is important to note that a gap still exists in pre-college achievement and interests in certain STEM fields among genders and ethnicities (Riegle-Crumb, Moore & Ramos-Wada, 2011).

The present study examines lasting effects of a middle school university partnership program on high school students' career interests. This study was guided by the following two research questions: (1) Do students involved in a middle GK-12 program develop significant changes in STEM interest and confidence during their involvement or afterward? (2) Does the GK-12 program affect the STEM interest and confidence of males and female students differently during their involvement or afterward?

GK-12 Description

In 1999, the National Science Foundation (NSF) began funding awards for the Graduate STEM Fellows in K-12 in Education (GK-12) that paired graduate student scientists with K-12 classroom teachers. GK-12 programs generally followed one of two models (Mitchell et al., 2003). The *exposition model* offered some limited opportunities for scientists to present to K-12 students and teachers. The *classroom immersion model* paired the scientists with K-12 teachers in a science classroom throughout an academic year. A majority of GK-12 programs, including the study at hand, used the latter approach. However, GK-12 awards ended in 2011, partly due to its high cost, time investment, and practical sustainability (Ufnar, Kuner & Shepherd, 2012).

Researchers have found positive effects of GK-12 programs related to improving scientists' confidence and communication (Feldon et al., 2011; Page, Wilheml, & Regens, 2011), teachers' pedagogical content knowledge (Mitchell et al., 2003), students' STEM learning (Mitchell et al., 2003), and even GK-12 students' interest in future STEM careers during their program involvement (Mitchell et al., 2003). However, research into whether STEM interest or confidence is maintained is notably absent, even with current calls to measure the effect of engaging STEM programs in middle school (Christensen, Knezek, & Tyler-Wood, 2015). This study aims to fill that gap.

The GK-12 program in the present study was a five-year partnership between a university, a public school district, and the NSF. One of the primary goals of this GK-12 program was to engage students in authentic science practices; consequently, the program was intended to increase student interest in STEM fields. The GK-12 scientists received summer training with and without their teachers to prepare them for classroom experiences and develop instructional lessons. During the school year, the scientists taught middle or high school students in their science classes one full day a week. For the purpose of this study, all scientists had taught in a middle school classroom. The GK-12 scientists were doctoral students across science and engineering programs at a large, Midwestern university. Their program areas included agronomy, biology, genetics, engineering, chemistry, and the natural sciences.

The scientists worked closely with classroom teachers to design engaging instructional lessons related to students' science district curriculum. Often, the scientists created lessons from their research interests, such as computer coding, natural environment

sustainability, or flight engineering. A small sample of classroom activities and pedagogy they provided included learning about, designing, and creating: musical instruments, robots, biodiesel, and genetically- modified plants. Some scientists worked in the schools for two years.

Methods

In this section, we report on the schools and student participants in this study. Then, the two surveys, administered at three points between middle and high school, are described. Finally, data analysis methods are explained.

Participants

Schools. Students currently enrolled in two high schools who had previously participated in a GK-12 program at one of three middle schools participated in this study. Both schools were located in a large, urban public school district with a community population of over 200,000. These schools acted as feeder schools from the middle schools in which the GK-12 program took place, so it was assumed that these high schools would have a large number of prior GK-12 students. Both schools served students in grades 9-12. School A enrolled about 1,000 students, 187 of which participated in this study. About 19% of its students were of Hispanic background, 25% were Black, and 34% were White. About 75% of its students were eligible for free or reduced lunch services. In this study, approximately 39% of juniors and seniors in this school participated in this study. School B enrolled about 2,100 students, 135 of which participated in this study. Approximately 22% of its students were Hispanic, 11% were Black, and 55% were White. About 66% of its students were eligible for free or reduced lunch services. Approximately 13% of juniors and seniors in this school participated in this study.

Participants previously attended three middle schools as seventh or eighth grade students. All three middle schools were in the same school district. The first middle school enrolled 750 students with about 61% White, 39% non-White, and 67% free or reduced lunch eligible. The second middle school enrolled about 700 students, with about 46% White, 54% non-White, and over 80% free or reduced lunch eligible. The third enrolled about 740 students, with about 30% White, 70% non-White, and about 76% eligible for free or reduced lunch.

Students. All juniors (grade 11) and seniors (grade 12) at both schools were surveyed, resulting in 784 respondents (52% of all juniors and seniors in the two schools). Of those respondents, 322 students (21% of all juniors and seniors) had a previous GK-12 experience and were included in this study, although not all provided demographic information on their surveys. Table 1 lists the available student participant demographic information.

Table 1. *Frequency of Demographic Characteristics of Study Participants*

	Total	Gr. 11	Gr. 12	Males	Females	Black	Hispanic	White	Other Ethn.
Overall	322	143	179	146	163	46	31	163	56
School A	187	101	86	91	87	23	18	82	44
School B	135	42	93	55	76	23	13	81	12

Surveys

Middle school survey. During students' year of middle school GK-12 involvement, they completed a pre-survey in August and a post-survey in April. The evaluators of the university's GK-12 program developed the paper survey. These surveys measured students' attitudes, perceptions, interests, and confidence in STEM areas. The GK-12 scientists administered them during instructional time. At both administrations, students responded to Likert-type items (rated 1-4) asking them about their interest in STEM fields (rated from 1 = Not Interested to 4 = Very Interested) and confidence in STEM areas (rated from 1 = Not Confident to 4 = Very Confident). Technology was always phrased as *computer science*. Students were given a unique identification code so pre-surveys, post-surveys, and their later high school surveys could be matched for analysis.

High school survey. During the fifth year of the GK-12 program, a follow-up survey was administered to juniors and seniors at two high schools. The survey was developed by the same evaluators and was vetted by personnel at the high schools to examine language and readability. These surveys included many of the same items as the middle school survey, and on the same scale (rated 1-4). Additionally, it contained items asking about students' STEM experiences and involvement in the time period between middle and high school, as well as future STEM plans and interests. The paper surveys were administered by teachers during periods considered *home room/study hall* as to not disrupt instructional time. Research assistants entered results into a data set. The researchers matched students by their identification code and merged the results with the middle school surveys for analysis.

Analyses

A repeated measures Analysis of Variance (ANOVA) provided significance of STEM interest and confidence means at the beginning of students' middle school GK-12 experience, at the end of their GK-12 experience, and then during their present point high school. Next, an independent samples *t*-test determined significance of differences between males and females in STEM interest and confidence in middle and high school.

Results

Changes in STEM Interest and Confidence

The first set of findings addresses Research Question 1: Do students involved in a GK-12 program develop significant changes in STEM interest and confidence during their involvement or afterward? Students in this study were previously involved in GK-12 in middle school (n = 322). Results of these 4-point, Likert-type responses in middle and high school were analyzed for three points in time (middle school pre-GK-12, middle school post-GK-12, and high school). A repeated measures ANOVA determined if means differed significantly between any of these time periods. There were no significant outliers in the data, and the dependent variables were normally distributed. Mauchly's test indicated that the assumption of sphericity had been violated; therefore, degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity. All analyses were run at the 95% confidence interval.

Post hoc tests using the Bonferroni correction showed that the mean differences of students' interests and confidence in STEM varied (see Table 2). There was no significant difference between the overall means of STEM interest and confidence (labeled *composite*) before and after the year of GK-12 (pre-post$_1$), but significant losses occurred between the end of GK-12 and high school (post$_1$-post$_2$) in STEM interest and confidence.

When examined by specific STEM areas, small but significant losses occurred in science and technology during the GK-12 year, but no other significant differences were found in other areas of STEM interest or confidence. However, from middle school to high school, significant losses occurred in science confidence (*m* difference= -.18), technology interest and confidence (*m* difference = -.82, -.56, respectively), and mathematics interest and confidence (*m* difference = -.70, -.44, respectively).

Next, differences in interests and confidence were calculated between the middle school pre-GK-12 and high school points (pre-post$_2$). This determined if there were significant and lasting effects overall between where students started in middle school and where they ended in high school. With the exception of engineering interest and confidence (*m* difference = -.06, -.15, respectively), students' interest and confidence in science, technology mathematics significantly declined. The greatest declines were in technology interest and confidence (*m* difference = -.94, -.64, respectively).

It appears that the GK-12 program had no significant positive effects on students' self-reported interest or confidence in STEM areas during the program year itself, or afterward. However, the majority of the losses in STEM interest and confidence came after students' involvement in GK-12, or during the point between middle school and high school.

Table 2. *Changes in STEM Interest and Confidence, Middle School to High School*

	Middle School Pre-GK-12 (pre)			Middle School Post-GK-12 (post$_1$)			High School (post$_2$)			Diff. pre-post$_1$	Diff. post$_1$-post$_2$	Diff. pre-post$_2$
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*			
STEM Interest												
Composite	**313**	**2.75**	**.71**	**313**	**2.75**	**.73**	**313**	**2.31**	**.72**	**0.00**	**.44*****	**.44*****
Science	310	2.84	.92	310	2.71	.97	310	2.61	1.05	-.13.*	-.10	-.23**
Tech.	303	3.09	.98	303	2.97	1.02	303	2.15	1.06	-.12.*	-.82**	-.94***
Eng.	305	2.39	1.12	305	2.47	1.14	305	2.33	1.06	.08	-.14	-.06
Math	311	2.71	1.03	311	2.83	1.00	311	2.13	1.00	.12	-.70***	-.58***
STEM Confidence												
Composite	**288**	**2.84**	**.63**	**288**	**2.80**	**.62**	**288**	**2.46**	**.60**	**-.04**	**.34*****	**.38*****
Science	283	2.87	.82	283	2.75	.85	283	2.57	.83	-.12*	-.18**	-.30***
Tech.	277	3.16	.86	277	3.08	.92	277	2.52	.90	-.08	-.56***	-.64***
Eng.	279	2.39	1.05	279	2.39	1.03	279	2.24	.85	.00	-.15	-.15
Math	283	2.98	.92	283	2.95	.93	283	2.51	.72	-.03	-.44***	-.47***

Note: Diff. pre-post$_1$ is the difference between middle school means prior to GK-12 and after GK-12. Diff. post$_1$-post$_2$ is the difference between means after GK-12 and in high school. Diff. pre-post$_2$ is the overall difference between middle school means prior to GK-12 and in high school. * $p < .05$, $p < .01$, ***$p < .001$

STEM Interest and Confidence of Males and Females

The second set of findings addresses Research Question 2: Does the GK-12 program affect the STEM interest and confidence of males and females differently? An independent samples *t*- test found significant differences between means of males and females in 11 of the 16 STEM interest and confidence areas. It is important to note three points. First, the means of males was always higher than females in these 11 areas. In fact, the mean STEM interest and confidence was higher for males in every STEM area at every measured point with only one exception: high school science confidence (*m* diff = .06, *p* = NS). The third issue to note is that significant differences were almost exclusively present in middle school;

by high school, significant differences only existed between males and females in engineering interest. Figure 1 displays the composite mean STEM interest and confidence of males and females at the three measured points.
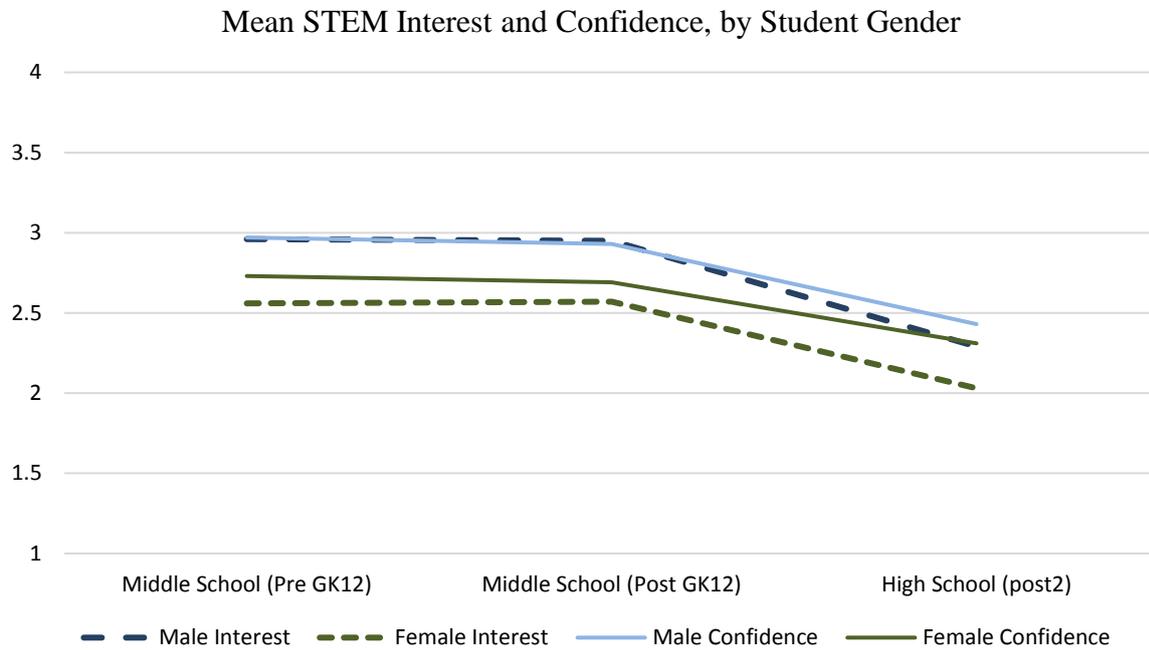
Mean STEM Interest and Confidence, by Student Gender

Figure 1. Graph of mean composite STEM interest and confidence by student gender at the beginning and end of middle school GK-12 involvement (PreGK12) and in high school. 1 = Not interested/confident, 2 = Slightly interested/confident, 3 = Interested/confident, 4 = Very interested/confident

Discussion

The results of this study were discouraging. Students did not gain an interest in STEM (as was one of the program's goals); in fact, they generally lost interest and confidence in science, technology, and mathematics. The goals of university partnership programs vary, but they often contain elements targeting the university partners, school partners, and particularly the K-12 students. While research has indicated that these university partnership programs are beneficial for the university fellows (George & Tankersley, 2013) and teachers (Lyons, Thompson, & Addison, 2007), we cannot conclude that this partnership structure (placing a scientist in a middle school classroom once weekly for a school year) positively affected students' interest or confidence in STEM. Although these scientists were taught about middle school settings and pedagogy prior to the program, and worked carefully with their partner teachers and university staff to plan engaging lessons, it was still not enough. It was not verified that the partnership program helped students feel they could be successful in or want to pursue careers in STEM during their involvement period or afterward.

When analyzing students by gender, the results of this study are similar to Sadler and colleagues (2012) in that males in our study were generally more interested and confident in STEM fields in middle school. Similar to the results of Sadler et al., females' overall interest and confidence in STEM declined from middle to high school. We found, however, that males' interest and confidence also declined. By high school, there were no longer significant difference between males and females (with the exception of engineering

interest). Although the gaps between males and females narrowed, the fact that they both declined over time should not be considered successful.

Like the results of Sadler et al. (2012), high school females in this study had significantly less interest in engineering than males. Previous research found female students developed greater perceptions and interest in engineering through working with engineering GK-12 fellows (Thompson & Lyons, 2008). Only two of the GK-12 fellows in this study were from an engineering program. It is possible that many of these female students did not receive a role model in those fields, and were, accordingly, less interested in them.

Christensen, Knezek, and Tyler-Wood (2015) concluded that STEM interests are formed early in a child's schooling; perhaps middle school is not early enough to reverse the effects of gradually losing interest and confidence in STEM. The literature suggests that elementary school may be a more appropriate point of partnership for universities who aim to increase STEM interest and confidence, and eventual career choice (DeJarnette, 2012). We highly recommend additional comparative analyses of university science partnership programs offered at various K-12 levels to further explore this.

It is reasonable to assume that students got little exposure to engineering concepts in their K-12 schooling. Engineering content in science classes is notoriously absent (Kesidou & Roseman, 2002), and engineering courses are not a part of a high school graduation requirement in the state the study was conducted. Additionally, most science teachers are unaware of how to teach students about engineering, both as concepts and as careers (Karatas, Micklos, & Bodner, 2011). The Next Generation Science Standards were revised recently to ensure that concepts of engineering were being addressed in all schools, because "engineering wasn't in most states…a child could go through K-12 school without finding out what an engineer does" (Cardno, 2013, p. 26). We feel that more deliberate teaching of engineering concepts may help close the high school gender gap in engineering career interest that was present in our study.

The NSF has since phased out the GK-12 program, but other university STEM partnerships exist. The unfortunate fact is that most schools, and even universities, do not have the resources or the viable option to partner with scientists or place their scientists in K-12 schools. Teachers, districts, and universities must continue to find ways to provide students with formal and informal authentic, engaging STEM experiences. It is clear from our results that students are in jeopardy of losing interest and confidence in STEM from middle to high school, so engaging STEM education should be in place all the way through a student's K-12 experience.

Limitations

One limitation of this study is that there is not enough information about the particular pedagogical contexts within the middle school GK-12 classrooms to explain differences, particularly the instruction that was provided on days the GK-12 scientists were not in the schools. The attitudes and pedagogy of particular scientists may have affected students' interests and confidence in different ways. Also, factors that occurred between middle and high school likely had an effect on the closed gaps we found between males and females, but we cannot account for those variables. Finally, there was no control group. As a result, it is difficult to definitively claim that the GK-12 program was solely responsible for effects on interests and confidence. Due to this, the results of this study should be interpreted somewhat cautiously and serve as a call to examine these findings with a control group to isolate variables that may be affecting STEM interest and confidence during and after university partnership programs.

Conclusion

Results of this study found that a multi-year, multi-million dollar, NSF-funded program did not result in an increase in students' STEM interest and confidence, either during their middle school years or maintained later in high school. In fact, overall results found that students significantly lost interest and confidence in all STEM areas except engineering. Although significant differences were found between males and females, the gender gap was generally closed by high school. Because there was no control group, it is not clear if the participants' school peers similarly lost interest in STEM during that phase. Still, we recommend that universities partner with schools at the elementary level to tap into students' STEM interests and develop their confidence early on. Additional research should examine differences that exist at the high school level between students with and without a previous STEM intervention experience to explore factors contributing to differences in STEM interest and confidence, and further tease out the long-term effects of university STEM partnerships. Finally, further investigation is warranted to examine this study's findings that students did not significantly lose interest and confidence in engineering, even though this is the STEM content area least often addressed in K-12 schools.

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