TECHNOVATION LOOKBACK REPORT:

A Retrospective Survey of Five Technovation Cohorts (2010-2014)

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Rockman et al
Research & Evaluation

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Introduction

Jobs in the technology industry, and specifically, jobs that utilize computer-programming skills, currently comprise one of the highest paying sectors in the U.S. economy. The number of computer programming jobs in the US is projected to grow twelve percent over the next ten years, faster than average for all occupations (U.S. Bureau of Labor Statistics, 2016). While the demand for labor in computer science-related professions is projected to grow, the absolute number and proportion of women earning computer science degrees has dropped dramatically since 1986, when women earned approximately 15,000 CS degrees, representing 37% of CS bachelors degrees awarded that year. In 2010-11, women earned approximately 7,500 CS bachelors degrees, representing only 12% of the CS bachelors degrees awarded, (NCES, 2012). The underrepresentation of women in the technology sector is even stronger in leadership positions, with 30% of technology leaders stating that their groups have no women in leadership positions (Zieminski, 2012). Another study found that women hold only 11% of executive positions at Silicon Valley companies, compared to 16% at companies in the S&P 100, (Fenwick & West, 2014). These trends have prompted advocacy communities to support women's pursuit of computer science jobs and leadership positions in the technology sector.

A larger tradition of research has identified patterns of gendered-behavior and gendered group dynamics, such as women's tendencies to downplay their contributions and accomplishments and to help others as linked to male domination in an already male-dominated field, (Ridgeway, 2011). Additional research on gender and organizational behavior has linked women's underrepresentation in leadership positions with women's access to informal networking opportunities, (Ridgeway, 2011).

While decades of research have addressed the broad underrepresentation of women in STEM fields, and women have been making gains in STEM fields such as Biology, Chemistry, and Earth, Atmospheric and Ocean Sciences, women have been losing significant ground in the field of Computer Science since the mid-eighties (Hill, Corbett, & St Rose, 2010). Specific reasons why women are underrepresented in computer science have been attributed to multiple causes, including stereotypes and cultural expectations, implicit bias, lack of diverse faculty and erroneous beliefs about intelligence (Hill, Corbett & St. Rose, 2010). The converse approach, understanding why women choose to pursue CS, was recently examined by a national survey of women in CS professions. According to this study, women who chose to pursue computer science were more likely to have received encouragement to pursue CS from parents, siblings, teachers, role models, peers and media, to have been exposed to diverse applications and positive societal impacts of computing, and to have had access to computer science courses in school and after-school programs (Wang, Hong, Ravitz & Ivory, 2015).

Technovation is a program designed to reduce the gender gap in computer science degrees and related professions by providing young women with an accessible, entry-level coding experience, scaffolded by peer and mentor support, and training in entrepreneurship and business leadership. The program centers on an annual challenge to design an app that addresses a local community problem. This enables young

women to pursue relevant interests while engaging in a "hands-on" curriculum that integrates coding and entrepreneurship lessons. The integration of these activities aims to develop young women's interest and skills in CS as well as their interest and skills in entrepreneurship and business leadership. By demonstrating how coding can help others, the program also addresses a general career preference that young women express to pursue a career that helps others (Diekman, Brown, Johnston, & Clark, 2010). The motivation to develop an app that helps others may also help to engage and develop girls' persistence in CS, as prior research has suggested (Wang, Hong, Ravitz & Ivory, 2015). Technovation also facilitates social learning and the development of local communities of practice by connecting girls with teachers who coach 3-4 person teams through the challenge. Between the initial 2010 cohort and the 2014 cohort, 2,786 young women completed the Technovation program.

Technovation is one of several "outside of school" programs designed to broaden underrepresented groups' participation in and access to computer science. These programs are designed to be engaging and accessible, and hence, tend to be increasingly short term, (e.g. "Hour of Code). There is a tension inherent in designing a program that is intended to be accessible enough to engage youth who have never tried coding before, while also developing enough interest in coding to have longer-term impacts that address a projected shortage in the US labor force. Evaluation of program participants' career aspirations after short-term programs may not necessarily provide valid or reliable evidence about their future behaviors as middle and high school students may not yet be able to accurately predict their future career choices. Evaluation of longer-term impacts of brief programs typically requires gathering data from matched samples over longer time periods, which can be difficult in practice. Thus, the present study uses a method of evaluating long-term outcomes through a follow-up survey at least four months after program participation, while including retrospective items to assess more immediate, and potentially short-term program-specific outcomes. We then use regression analyses to examine the correlation between program-specific outcomes and longer-term behaviors, such as course taking and declaring a college major in Computer Science or Business.

As many organizations and institutions advocate for gender equity in computer science and related fields, few targeted interventions to support young women in pursuing computer science have examined long-term outcomes. The present study contributes to this literature by providing an analytical framework to evaluate the correlation between proximal, program-specific outcomes and longer-term outcomes. In addition, we report on the impacts of an accessible and relatively brief, project-based computer science intervention designed to promote young women's pursuit of computer science and entrepreneurship. The present study examines qualitative and quantitative evidence of proximal impacts on young women's interest in computer science and business leadership/entrepreneurship, as well as the relationship between these proximal outcomes and subsequent majoring and course taking in computer science, at least four months and up to five years after participation. Since Technovation is designed to develop interest, entrepreneurship, and persistence in CS in an integrated manner, we expected participants to report high levels across these outcomes, at both the proximal and longer term levels. Our research questions are summarized as follows:

RQ1: What were the specific impacts of Technovation, based on retrospective reports?

RQ1a) To what extent do Technovation participants agree that the program *increased* their interest in Computer Science, Entrepreneurship, or Business Leadership?

RQ1b) To what extent do Technovation participants report that they are still working on their Technovation project? What are the reasons that they report persisting or not persisting?

RQ1c) To what extent are specific, proximal outcomes correlated, thus indicating integrated or discrete program impacts?

RQ1d) To what extent do proximal outcomes vary by participants' grade level-range at the time of their participation?

RQ2: To what extent do specific self-reported impacts of Technovation predict subsequent participation in formal Computer Science education?

RQ2a) To what extent does the impact of Technovation on interest in Computer Science predict self-reported likelihood of pursuing Computer Science in college (e.g. enrolling in Computer Science courses and majoring in a Computer Science or related field)? To what extent is this relationship moderated by participants' grade-level range, (middle school or high school), at the time of their participation?

RQ2b) To what extent does the impact of Technovation on Computer Science interest predict subsequent enrollment in any type of Computer Science course? To what extent is this relationship moderated by participants' grade-level range, (middle school or high school), at the time of their participation?

RQ2c) Among respondents enrolled in a college or university at the time of the follow-up survey, to what extent does the impact of Technovation on Computer Science interest predict subsequent majoring in Computer Science? To what extent is this relationship moderated by the participants' grade-level (middle school or high school) at the time of their participation?

RQ2d) Among respondents enrolled in a college or university at the time of the follow-up survey, to what extent does the impact of Technovation on interest in Entrepreneurship and Business Leadership predict subsequent majoring in Business or Economics? To what extent is this relationship moderated by the participants' grade-level (middle school or high school) at the time of their participation?

Methods

Two surveys were administered by Technovation and provided to Rockman et al, an independent research and evaluation firm, for analysis. The first survey was conducted in January 2014, (N=117) as a pilot, the second in September 2014 (N=653). Several key items were similar or identical across the surveys;

however, due to measuring *confidence* versus *interest* on key outcomes in Survey 1, it was not possible to merge the two datasets in order to maximize the sample size. Thus, the larger dataset (*N*=653) was used to examine the two Research Questions (described above) across the five cohorts (2010, 2011, 2012, 2013, 2014). The smaller dataset (*N*=117) was used to provide additional qualitative data about Technovation experiences in order to address RQ1b. Technovation invited all former Technovation participants for whom contact information was available to participate in the surveys via email. Survey invitation and response rates by cohort are provided in Appendix A.

Technovation's proximal impacts on computer science interest and entrepreneurship. Proximal impacts were assessed through four questions. Alums were asked to rate the extent to which "*Technovation made me more interested in...*" each of three areas: *Computer Science*, *Entrepreneurship*, and *Business Leadership*, using a 5-point scale ranging from Strongly Disagree to Strongly Agree, with a midpoint of "Not Sure." In addition, alums were also asked if they were still working on a Technovation project, ("Are you still working on Technovation related project?"). The surveys also included slightly different versions of open-ended questions to elicit further information about Technovation projects on which alums were still working. In the first survey with the smaller sample, participants were asked "If [you are still working on a Technovation related project], please explain (For how long? How far did you get? Are you still working on it or why did you stop?)." The second, larger survey used a more open-ended prompt, "If you are working on a Technovation project, we'd love to hear about it!" The first survey also included an open-ended prompt at the end of the survey asking participants to provide any comments or suggestions about their Technovation experience. Qualitative data elicited from both surveys were analyzed to provide context about participants' Technovation experiences and why participants persisted on Technovation related projects or not.

Participation in Computer Science courses after Technovation. Since the majority of participants were not in college at the time of the survey, several types of CS course taking that would be expected among high school respondents were measured, "Did you take any of these courses after Technovation? Check all that apply…" with course options of "AP Computer Science," "Other High School Computer Science or Programming Course," "Extracurricular computer science or programming course," and "Other Computer Science or Programming Course. Please specify." Qualitative responses for "Other" courses were analyzed and coded as 1 if they were Computer Science courses not referenced by the other categories. Participation in CS courses after Technovation and before college or university enrollment was calculated for each respondent as the sum of CS courses that each took after Technovation.

Likelihood to pursue CS education in College or University. Since many participants were not in college at the time of the survey, participants were asked to indicate their likelihood of majoring in CS or a related field, and taking CS courses in college or university, on a five-point Likert scale, ranging from "Definitely will not" to "Definitely will or already have" with a midpoint of "Not sure" in response to a three-pronged prompt: "*In college, how likely are you to choose…"* followed by: "*Computer Science as a major*," "*At least one or two Computer Science courses*," and "*A field that uses Computer Science (such*

as Information Technology, Engineering, etc)." The alpha coefficient for responses to these three items of .83 suggests the items have high internal consistency. (A reliability coefficient of .70 or higher is considered "acceptable" in most social science research situations). We also performed a factor analysis to investigate the dimensionality of the scale and to determine whether the three items could be consolidated into a single construct. Looking at the total variance explained, the eigen value for the first factor was larger than the eigen value for the next factor (2.24 versus 0.411), and accounted for 75% of the total variance, suggesting that the scale items are unidimensional. Thus, an overall measure indexing participants' likelihood to pursue computer science in college or university was constructed by computing the mean score for responses to these three items.

Declared major in college or university. Respondents were asked if they were enrolled in college or university at the time of the survey, and if so, they were asked to report their declared or planned major using a free-response format. Responses were classified according to whether the declared or planned major fell into each of the following three fields, coded 1 or 0: Computer Science, Business/Economics, and STEM, (with STEM excluding Computer Science majors).

Sample Characteristics

The present analysis focuses on Technovation participants who were in high school, middle school or elementary school at the time of their participation.[1] Respondents who were not in high school, middle school, or elementary school, or who were over 18 years of age at the time of their participation in Technovation were excluded from the present analysis. To ensure that only Technovation participants were included in the sample, respondents who did not identify the year(s) in which they participated in a Technovation cohort were also excluded from the analysis. After filtering out the aforementioned respondents, 579 responses were examined for impacts on subsequent CS interest, and CS course taking and majoring in CS or Business in a college or university.

As shown in Figures 1 and 2, approximately four out of five respondents participated in Technovation during high school (84%, *N*=488). Most participants were aged 15-19 at the time the survey was administered, (75%, *N*=418). Six respondents repeated the Technovation program and thus participated during both middle school and high school.

[1] Technovation is designed primarily to serve young women in middle and high school; however, college students can participate in the High School Division if they do not exceed the maximum age of 18, per the Official Rules. College students were excluded from the present analysis in order to minimize a ceiling effect on subsequent course taking and majoring in Computer Science and/or Business in college or university after Technovation. Young women who participated in Technovation more than once, and who were in high school and college during their participation were retained in the sample.

Figure 1. Grade Level Ranges at Time of Technovation Participation

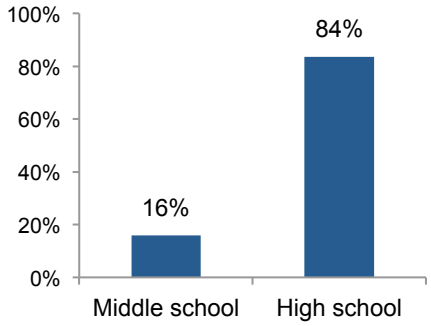
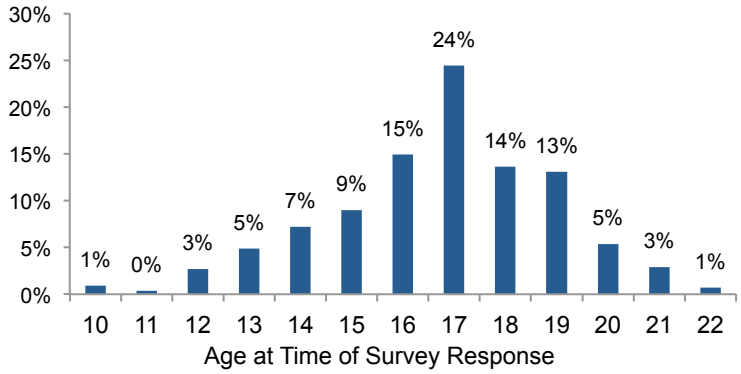
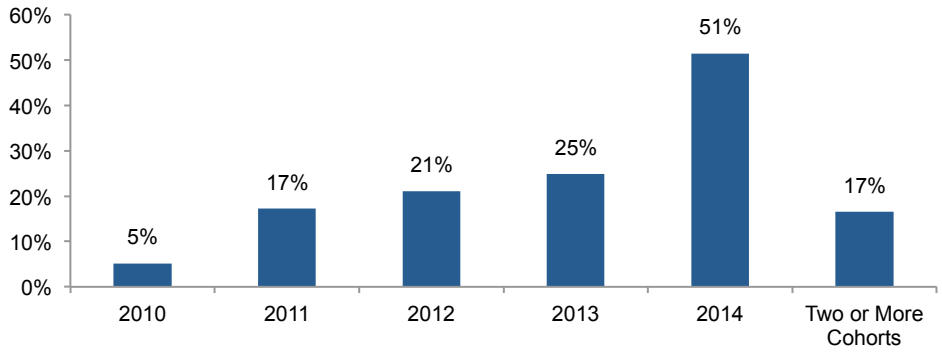


Figure 2. Distribution of Age at Time of Survey Response



The majority of respondents (76%, N= 442) participated in the 2013 or 2014 Technovation cohorts. About one out of six respondents (17%) repeated the program, and thus, participated in two or more cohorts (N=98). Among respondents who repeated the program, 14% participated in two cohorts, 2% participated in 3 cohorts and three respondents participated in four cohorts.

Figure 3. Participation in Technovation Cohorts



Technovation Proximal Impacts

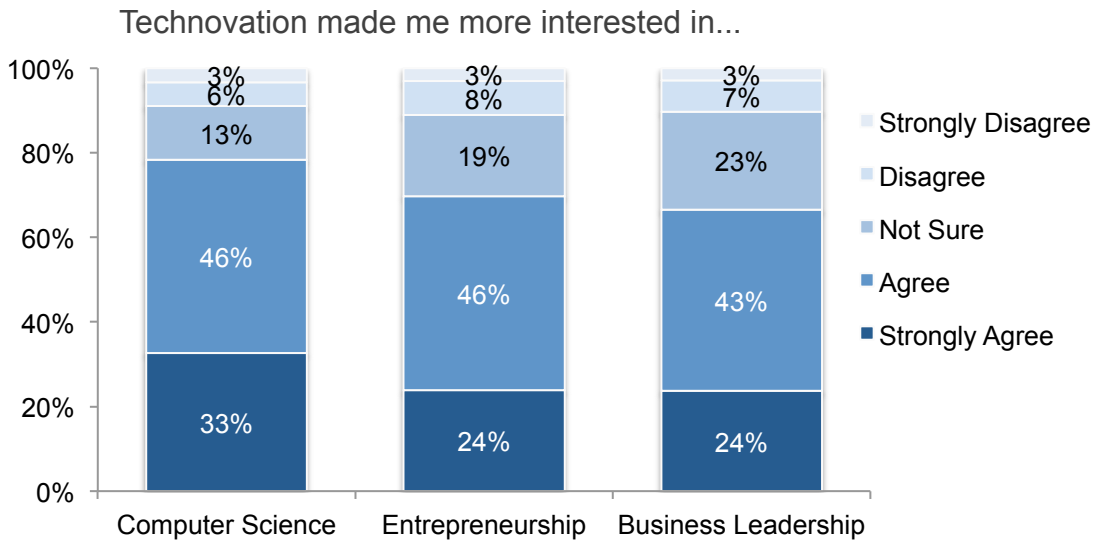
Technovation is designed to increase interest in Computer Science, Entrepreneurship and Business Leadership, as well as persistence in developing apps. The follow-up survey examined these four key proximal outcomes, as well as the correlations among them.

Interest in Computer Science, Entrepreneurship, and Business Leadership

As expected, the majority of respondents agreed that Technovation increased their interest in the targeted fields: ***Computer Science*** (78% agreed, N=454), ***Entrepreneurship*** (70% agreed, N=404), and ***Business Leadership*** (67% agreed, N=385). Independent samples t-tests were conducted to compare participants' levels of agreement that Technovation increased their interest in these fields according to whether they participated in Technovation during middle school versus high school, and showed that mean levels of

increased interest in these fields did not differ according to grade level.

Figure 4. Technovation Impacts on Interest in Computer Science, Entrepreneurship and Business Leadership



Technovation Project-Persistence

Approximately one out of six survey respondents was still working on a Technovation project at the time of the survey, (17%, N=97). Among the respondents still working on Technovation projects, most were doing so with a team (70%, N=68), while the rest continued on their own (30%, N=29). Middle school participants were more likely than high school participants to report working on their Technovation projects at the time of the survey; approximately 24% of middle school students were still working on their projects at the time of the survey, compared to 16% of high school students. Among the middle school participants still working on Technovation projects, (N=21), most worked with a team (N=14). Among the high school participants still working on their Technovation projects, (N=72), most were also working with a team, (N=50). Among the six respondents who participated in Technovation during both middle and high school, four persisted on projects, all with a team.

Respondents were also asked to provide further information about the Technovation projects on which they are still working. A thematic analysis of these free-response project descriptions revealed that high school students were more likely to cite lack of time and competing commitments, such as school and work, as primary reasons they were no longer working on Technovation projects. An additional common theme that emerged from the analysis of open-ended responses concerned support for the development of apps after the contest. Some teams secured development support through their own or external funding, while other teams cited struggling with finding or not having development support as a reason they were no longer working on their projects, (See Appendix B for quotes about project experiences).

Correlations Among Technovation Proximal Outcomes

As shown in Table 1, the four key proximal outcomes of Technovation were significantly correlated, suggesting that the programming has an integrated impact on these outcomes. Participants who agreed that Technovation increased their level of interest in Business leadership were highly likely to also agree that Technovation increased their interest in Entrepreneurship, ($r = .74$, $p < .01$). Agreement that Technovation increased participants' interest in Computer Science and Entrepreneurship showed the next highest correlation, ($r = .30$, $p < .01$), followed by Computer Science and Business leadership, ($r = .27$, $p < .01$). Participants who reported that Technovation increased their interest in Entrepreneurship and Business leadership were more likely to report continuing on their Technovation projects at the time of the survey, ($r = .23$, $p < .01$ and $r = .22$, $p < .01$, respectively), as compared to participants who reported that Technovation increased their interest in Computer Science, ($r = .13$, $p < .01$).

Table 1. Correlations Among Technovation Proximal Outcomes

Survey Items		*1.*	*2.*	*3.*	*4.*
1. Technovation made me more interested in Computer science	Pearson Correlation	1	.30**	.27**	.13**
	N		579	579	557
2. Technovation made me more interested in Entrepreneurship	Pearson Correlation		1	.74**	.23**
	N		579	579	557
3. Technovation made me more interested in Business leadership	Pearson Correlation			1	.22**
	N			579	557
4. Are you still working on a Technovation related project?	Pearson Correlation				1
	N				557
**. Correlation is significant at the 0.01 level (2-tailed).					

Technovation Impacts on Computer Science Course-Taking and Majoring in Computer Science

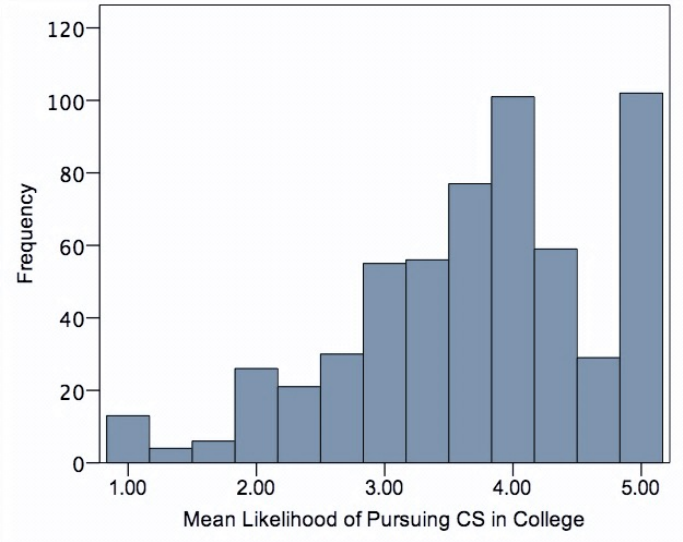
In subsequent analyses, we sought to examine correlations between proximal (specific) Technovation impacts and subsequent participation in formal Computer Science education, including Computer Science courses and majoring in Computer Science in a college or university, as well as formal Business education, including majoring in Business or Economics in a college or university. We conducted separate regression analyses to examine the extent to which short-term Technovation impacts predicted longer-term outcomes, and the extent to which grade level-range moderated these relationships.

Self-reported likelihood of pursuing Computer Science in College

Half of Technovation participants, (50%, $N = 291$), reported they will definitely or probably pursue Computer Science in college or university ($M = 3.71$, *Median* = 4.00, *Mode* = 5.0, $SD = .98$. $N = 579$), by taking one or two courses, and/or majoring in Computer Science or a related field. Figure 5 shows the

distribution of mean responses averaged across the three items used to construct the measure.

Figure 5. Mean Likelihood of Pursuing CS in College Among Middle and High School Technovation Participants



We used multiple regression to determine which constructs had the most predictive power for each outcome variable. The resulting regression of likelihood to pursue Computer Science in college on increased interest in Computer Science, Entrepreneurship and Business Leadership attributed to Technovation produced a three-variable model. Increases in Computer Science, Business Leadership and Entrepreneurship interest accounted for 21% of the variance in the likelihood to pursue Computer Science in college, ($F(3,575)=50.67$, $p<.001$). The strongest predictor was the extent to which respondents agreed that Technovation increased their interest in Computer Science. Increased interest in Entrepreneurship was a weaker predictor, while increased interest in Business Leadership was a weak and negative predictor of the likelihood to pursue Computer Science in college. Figure 6 shows the regression results with standardized β values for each of the predictor variables.

To examine whether grade level moderated these relationships, two additional regression analyses were run separately for middle school and high school participants (excluding six respondents who participated in Technovation during both middle and high school). The regressions of likelihood to pursue Computer Science in college on increased interest in Computer Science, Entrepreneurship and Business Leadership produced two separate two-variable models. Among middle school participants, the linear combination of increased interest in Computer Science and Entrepreneurship interest accounted for 41% of the variance in the likelihood to pursue Computer Science in college ($F(2,84)=29.49$, $p<.001$). Among high school participants, the linear combination of Computer Science and Business Leadership accounted for 17% of the variance in the likelihood to pursue Computer Science in college ($F(2,479)=50.54$, $p<.001$). Thus, increased interest in Computer Science due to Technovation remained a predictor of likelihood to pursue Computer Science in college across middle and high school participants; however, more variance in the outcome was accounted for among the middle school participants. Increased interest in Entrepreneurship

was a weak predictor of likelihood to pursue Computer Science in college among middle school participants only, while increased interest in Business Leadership was a weak, negative predictor among high school participants only. Figure 7 shows the regression models for middle school versus high school, with standardized β values for each of the predictor variables.

Figure 6. Model of Technovation's Influence on Likelihood to Pursue Computer Science in College

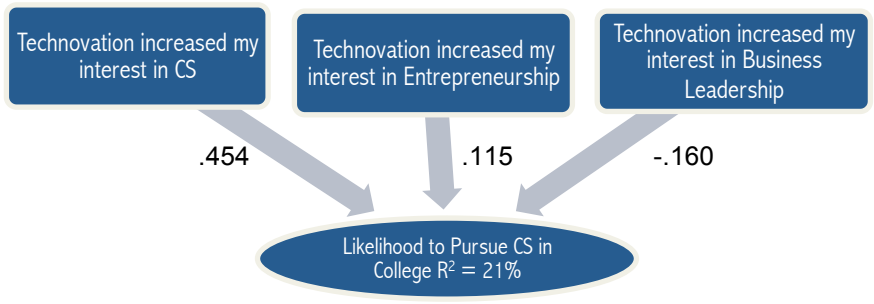
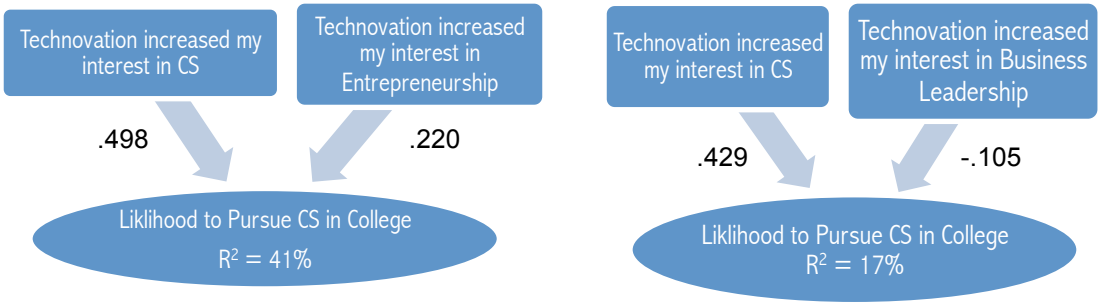


Figure 7. Middle School Model vs. High-School Model



Subsequent enrollment in Computer Science courses

After their participation in Technovation, more than half of respondents (58%) enrolled in a Computer Science course, (N = 336, *Mean number of courses* = 1.47, SD = .712). Furthermore, one out of five respondents (N=118) reported enrolling in AP Computer Science after their participation in Technovation. High school respondents took more CS courses after Technovation (M = 1.50, SD = .73) than middle school participants (M=1.21, SD = .434; t = 2.9, p <.01).

The resulting regression of enrollment in Computer Science courses on increased interest in Computer Science, Entrepreneurship and Business Leadership due to Technovation produced a one-variable model, with *decreases* in interest in Business Leadership (β =-.132, p<.05), accounting for only 2% of the variance in the likelihood to enroll in a Computer Science course, (F(1,334)=5.93, p<.05). This model accounted for very little variance, and suggests that Technovation did not have a strong correlation with subsequent enrollment in CS courses.

Subsequent majoring in Computer Science in college or university

Among the middle and high school Technovation participants, 211 (36%) had started college or university at the time of the survey; six respondents participated in Technovation during middle school and 204 during high school. Among these respondents who had started college or university, 170 provided their declared or planned major: 26% were majoring in Computer Science fields, including Information Technology, Computer Engineering or Software Engineering, (*N*=54; High School *N* = 54, Middle School *N* = 0), 33% were majoring in Non-CS STEM fields, most commonly Electrical or Mechanical Engineering, and Environmental Science and Biology, (*N*=70; High School *N* = 68, Middle School *N* = 2), 10% were majoring in Business or Economics (*N*=20; High School *N* = 54, Middle School *N* = 1), and 12% were majoring in a non-CS, non-STEM, non-Business major (*N*=26; High School *N* = 25, Middle School *N* = 1), such as Psychology, Nursing, Law or Communication.

Logistic regression was conducted to predict the extent to which increased levels of interest in Computer Science, Entrepreneurship and Business Leadership resulting from Technovation predicted majoring in Computer Science. A test of the full model versus a model with intercept only was statistically significant, *chi-squared* (3, *N* = 211) = 39.98, $p < .001$. The pseudo-R^2 indicated that the model accounted for roughly 25% of the overall variance in declaring a CS major among Technovation participants who had started college or university. Young women who agreed that Technovation increased their interest in Computer Science were 3.4 times more likely to declare a CS major, controlling for individual differences in increased interest in Business Leadership due to Technovation. However, young women who agreed that Technovation increased their Business Leadership interest were 50% *less likely* to declare CS as a major, again controlling for differences in increased interest in Computer Science due to Technovation. As the correlations in Table 2 show, Technovation's impact on CS interest was a stronger predictor of CS majoring than its impact on Business Leadership interest. Increased interest in Entrepreneurship resulting from Technovation was not a significant predictor in the model.

Logistic regression was conducted to examine the extent to which increased interest in Computer Science, Entrepreneurship and Business Leadership resulting from Technovation predicted Business majoring in college. The model was only marginally significant (p=.04), and the did not add any correct predicted classifications of business majors to the null model.

Table 2. Correlations Among Technovation Outcomes and College Major

Survey Items		1	2	3	4	5	6
1. Technovation made more interested in Computer science	Pearson Correlation	1	.19**	.22**	.31**	-0.02	-.15*
	N		211	211	211	211	211
2. Technovation made more interested in Entrepreneurship	Pearson Correlation		1	.69**	-0.1	0.122	-0.07
	N			211	211	211	211
3. Technovation made more interested in Business leadership	Pearson Correlation			1	-.17*	.17*	-0.07
	N				211	211	211
4. Majoring in Computer Science	Pearson Correlation				1	-0.12	-.32**
	N					211	211
5. Majoring in Business/Economics	Pearson Correlation					1	-0.13
	N						211
6. Majoring in Non-CS STEM field	Pearson Correlation						1
	N						211

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Discussion

Technovation participants reported strong levels of engagement with the program. More than two-thirds of Technovation respondents agreed that the program increased their interest in Computer Science, Entrepreneurship, and Business Leadership, and these responses were correlated, suggesting that the program has an integrated impact. Approximately 17% of respondents continued working on their Technovation project at least four months after the program ended, and even up to two to three years later. Among the initial 2010 cohort, 23% repeated the program. As the size of the 2014 cohort increased thirty-four fold, a comparable level of engagement was maintained, with nearly one out of five reporting that they had participated in the program before (19%). Middle school participants were most likely to persist on Technovation projects. High School participants cited lack of time and competing commitments at school and work as reasons they couldn't persist on their projects. Several participants also indicated they would have liked support after the contest in developing their apps and bringing their apps to market in the Apple store or Google Play Store.

Half of the participants (50%) reported they will probably or definitely pursue Computer Science in college or university, by taking CS courses and majoring in CS or a related field, with approximately 23% reporting that they will definitely do so. The extent to which respondents agreed that Technovation increased their interest in Computer Science significantly predicted their subsequent self-reported likelihood to pursue Computer Science in college, four months to several years after their participation in

Technovation. This relationship was stronger among middle school students than high school students. Among middle school students, Technovation's impact on increasing their interest in Entrepreneurship also increased their likelihood to pursue CS in college. Among high school students, the impact of Technovation on interest in Business Leadership showed a negative relationship to subsequent likelihood to pursue CS in college, suggesting that interest in Business Leadership is competing against the pursuit of CS in college.

Overall, the middle school regression model predicted twice as much variance as the high school regression model in participants' likelihood to pursue CS in college at follow-up, four months to four years after program participation, despite the fact that there were no differences in proximal impacts according to grade level. In other words, both middle and high school participants reported the same level of agreement about Technovation impacts on their interests in CS, Entreprenurship, and Business Leadership, but among middle school participants these impacts accounted for more variance in their longer-term attitudes about pursuing CS in college, as compared to high school participants. These results suggest that young women's self-reported likelihood to pursue Computer Science in college may be more malleable during middle school than high school, and that Technovation may be more transformational for middle school students, at least in terms of influencing their self-reported likelihood to pursue computer science in college. However, it is also possible that middle school Technovation participants differ from high school students in important ways that offer alternative explanations. For example, because middle school youth are learning computer science earlier in life, they may feel more confident about their future potential to succeed. In addition, middle school participants may be less reliable than high school participants in predicting their future behaviors, as high schoolers have had more time and experience to estimate their pursuit of computer science relative to competing fields and interests. In other words, because high schoolers may be more knowledgeable about their options, their predictions about their future choices in college may be more valid and reliable.

Among Technovation participants enrolled in college or university at the time of the survey, 26% reported that they were majoring in Computer Science. This rate is sixty-five times higher than the 0.4% national rate among first-year, female college students who report that they intend to major in CS, (Hill, Corbett, Rose, 2010). Young women who strongly agreed that Technovation increased their interest in CS were three times more likely to major in CS than those who did not agree, controlling for other individual differences. It is also notable that 33% of participants in college at the time of the survey reported majoring in a non-CS STEM major, with engineering most common, a rate that is twice the national rate of female college freshman who pursue STEM fields, (15%, according to Hill Corbett and Rose, 2010).

Surprisingly, young women who strongly agreed that Technovation increased their interest in business leadership were 50% less likely to major in CS than those who did not agree, controlling for other individual differences. Correlations indicated that Technovation's impact on CS interest was a stronger predictor of majoring in CS than Technovation's impact on interest in Business Leadership. Thus, the impact of Technovation on participants' interest in Business Leadership showed a suppression effect in

two regression models of longer-term outcomes: Majoring in CS and Likelihood to Pursue CS in College. Since two regression models suggests that increased interest in Business Leadership resulting from Technovation reduces the likelihood that the participants will pursue CS in college, Technovation may wish to explore possibly re-framing the Business Leadership curriculum so it is more focused on CS entrepreneurship.

However, as discussed in the next section, we do not know the magnitude of change in interests resulting from Technovation. It is possible that the threshold level of interest to motivate young women to major in CS in college exists prior to participation in Technovation. Thus, even if a young woman agrees that Technovation increased her interest in CS, her initial interest may have been sufficient to pursue CS, such that there was no transformation with respect to her subsequent decision to major in CS, except perhaps maintenance or protection of the interest from external factors. As discussed in the next section, further qualitative research would help to illuminate and contextualize the findings based on the present survey.

Since few middle school participants were enrolled in college at the time of the follow up survey, it was not possible to examine how the impact of Technovation on CS interest predicts actual majoring in CS in college. Among the middle school participants who were enrolled in college, and who had declared a major, three out of four indicated that they were incorporating technology into their academic goals.

Limitations and Future Directions

CS-participation outcomes develop from multiple sources. Thus, it is not possible to make causal claims about the role that Technovation played in perpetuating or promoting these interests based on the present survey. However, at the very least, the significant correlations between proximal impacts and longer term attitudes and behaviors observed in the present study provide evidence to rule out the possibility that Technovation has a null effect, or zero influence on subsequent participation in CS education.

Limitations of retrospective assessments of program impact. Baseline measures of the proximal and longer-term outcomes prior to program participation would help to more objectively estimate the magnitude of increases in proximal and longer-terms outcomes produced by Technovation. It is possible that through the self-reports participants were not able to disentangle the interest they had going into Technovation with the increased interest they had afterwards, so there is no assessment of the magnitude of change in CS interest resulting from Technovation. The survey could ask respondents to quantify their interest in the targeted fields before participating as well as after participating, in order to control for prior interest and quantify change that occurs. As baseline measures can be impractical, a future retrospective follow-up survey could ask participants to estimate how much Technovation increased their interest on a five- or seven-point scale, (e.g. ranging from “A great deal” to “Not at all”). Both methods would help to provide an estimate of interest going into the program, and thus help to address the question of whether Technovation is transformational or protective of young women's CS career aspirations. Either way, there is no evidence that the interest in CS that Technovation generated was unrelated to subsequent self

reported likelihood to pursue CS, nor was it unrelated to subsequent college majoring in CS.

Sampling: About 2/3 of all alumni did not receive the survey due to a lack of "working contact information." We propose to delve deeper into the issue of "working contact information" with Technovation staff, in order to better understand who was invited to participate in the survey in each cohort, and how the present survey sample may have been inadvertently biased by the invitation process being conflated with presence or absence of "working contact information." In order to better understand how we may generalize results based on the present survey data, and to more accurately characterize the sample of respondents in the present survey, further qualitative research may explore two key lines of inquiry:

- What percentage of each cohort was invited to the survey? Why was contact information missing? Were the program completers with missing contact information concentrated in any particular geographic regions?
- Among invited participants, were non-responders and responders equivalent in terms of geographic location and Internet access? A brief follow-up survey of randomly-sampled non-responders by phone or email would help to characterize the level of internet access and potentially, geographic location, among non-responders and responders.

Qualitative Research to Contextualize Trends and Correlations

Is Technovation transformational or protective? Qualitative interviews would help to address the question of whether girls would have pursued CS even if they did not participate in Technovation, or how Technovation influenced their decision to pursue CS. Initial qualitative evidence suggested that Technovation was transformational for at least a few particpants (See Appendix B), but a more systematic exploration is needed understand the extent to which such responses are representative. Although most of the sample reported Technovation increased their interest, it is possible that these participants had surpassed the threshold level of interest and motivation needed to pursue CS in college prior to Technovation. Baseline measures of likelihood to pursue CS and a more nuanced understanding of how Technovation participants decided to pursue CS or not would help to illuminate the role of Technovation in supporting young women's decisions to pursue a CS-related profession or not. For example, follow-up interviews and/or focus groups would help to illuminate how Technovation played an important role in sustaining interest, and/or protecting young women from other factors that may have deterred their pursuit of CS-related professions. Follow-up interviews would also help to characterize the level of internet access available to survey respondents.

While previous national survey research has identified factors that promote and deter CS participation (Wang, Hong, Ravitz & Ivory, 2015), a more detailed qualitative study would not only provide a valuable replication and extension of this research, it would also provide richer and more nuanced evidence about how multiple sources influence CS interest and participation, (e.g. CS-Majoring and CS-course-taking), and bidirectional relationships between CS interest and CS participation. This will enable us to understand the contextual issues and key social processes or other external factors that may contribute to

or detract from a student's interest in pursuing CS or other fields of study. For example, the percentage of alumns majoring in CS at follow-up may have been constrained not by student interest, but by caps on majors imposed by universities due to lack of faculty and infrastructure (Zweben, 2011).

In the pilot survey, *30% of respondents said they would be interested in being interviewed about their experience with Technovation, (N=35), and provided their email address and phone number.* Thus, we propose to contact these alums to see where they've ended up in terms of their educational and professional interests, and to obtain qualitative information in order to compare multiple sources of influence on CS-students' and non-CS students' career interests and goals, examining issues such as:

- What are alums' career goals, and how do these goals relate to their experiences with CS?
- What motivated alums to take CS courses and/or major in CS?
- What deterred alums from CS courses or from majoring in CS?
- What teaching strategies or elements of Technovation worked best for supporting learning about CS?
- What were the major challenges in learning CS?
- What did you learn through participating in Technovation?
- Did Technovation influence your educational or professional interests? How so?
- What advice would you give to future Technovation participants?

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Appendix A

As shown in Table A1, the first cohort started the program five years before the present survey was conducted and showed the highest survey participation rate of 68%. Survey participation rates decreased in subsequent cohorts as the size of each successive cohort grew.

Appendix Table A1. Survey Response Rates by Cohort

Cohort Year	Total Responses	Total Alumnae	Response Rate	Participants in Multiple Cohorts
2010	30	44	68.2%	10
2011	100	256	39.1%	26
2012	122	501	24.4%	47
2013	144	485	29.7%	73
2014	298	1500	19.9%	55
Total	694	2,786	24.9%	96

Appendix B

Appendix Table B1. Qualitative Data (Second Survey, *N*=579)

Responses to the item: "Are you still working a Technovation Project? If you are still working on a Technovation project, we'd love to hear about it!" (*N*=579)	
Middle School Participants still working on Technovation projects, (*N*=21, 24%)	"On our app GoGals with which we participated in Technovation 2014. We'd love to participate again!" "We're still working on a our last project." "I am working on a project that helps locate the tourist attraction site in my community" "Planning on re-entering this year with another school"
High School Participants still working on Technovation projects, (*N*=72, 15%)	"Developping a health care app for rural women to help locate doctors and nurses and clinics in their local and in urban commun ities" "Next year's Technovation app. We're doing something involving apathy and 2nd and 3rd world countries." "We are hoping to continue improving Club Connect, which is a social media platform for clubs at our school." "The Nightingale 2014 Technovation team is still working on Safeteen. So far, we've been meeting at Thoughtworks to determine our next steps forward." "I am thinking of developing an app for autism and also im working in a teamat my school" "GreenBaby app" "Currently, my team is still coding our app. We are trying to expand beyond AppInventor and use the cross-platform Apache Cordova. We have also reached out to our high school (Winchester High School, MA) and hope to beta test our concussion detecting app this winter. The TimeOut (now SafeSide) team, hopes to be able to make this app native to the various OS-es next summer. Relations with incubators such as Constant Contact have also been incredibly helpful." "Branna- skin sensoring app." "Creating a Study App" "Modifying the app we created, adding new features "NxtGen" "Working on developing our Tag It app" "We are further developing the app that we started in Technovation. "We're continuing our work on our app and trying to get funding to launch it." "We're planning to put our app in the market in a couple of years." "website development" "Working with StudyCafe to develop the app" "I am doing a self-study on programming courses." "I'm practicing :)" "I'm no longer part of technovation but I did participate as a tutor for middle school girls that were doing the same thing but in lower grades." "Will be participating in the challenge again in 2015."
Repeat Participants (High School & Middle School)	"we develop metier last year we are planning to redevelop it to the winning standard"

Appendix Table B2. Qualitative Data (Initial Survey, *N*=117)

Responses to the item: "Did you continue to work on your app- idea after Technovation program officially ended? If Yes, please explain (for how long? how far did you get it? are you still working on it, or why did you stop?) (*N*=117)	
High School Participants who persisted on Technovation projects, (*N* = 20, 17%)	"I work on it whenever I have free time. Whether on Google app invetir or I expand it to actual JavaScript." "I'm part of the 2012 winning team, and we decided to work on it because we believe it's still a cool idea. It's been going fairly slow, but we are getting close to a beta version..." "continue to work on it, trying to get help from technovation but it's proving to be challenging" "Our team invested in an developer who has been working on it since, I do not know the details of how it is coming on at this moment" "I am currently still working on it; the path has been difficult but I have a lot of hope for what my team can accomplish." "I am still working on it but I was planning to finilaze it after my mocks." "I worked with Kapor Capital, an angel investment firm in San Francisco, for one summer on my application with 2 other members of my Technovation group. The project was abandoned after that summer because the group dynamics fell apart under duress. I still have everything from the project though and am working on it as a side project this semester." "i'm still working to develop my app" "We are still working on our idea, trying to improve it." "We are working in which metod is better to put our app in the market and how $$$" "Worked on coding and refining it, we're still hoping to run a beta version at our school later"
High School Participants who were *no longer* working on Technovation projects, (*N* = 97, 83%)	"I was part of the winning team for 2011, so I worked on it for one more year until it was released on the Google Play Store and Apple App Store." "My group won Technovation Challenge in 2011, so our app was developed by Softserve and our team helped contribute ideas during development." "After the technovation challenge, i tried to continue working on the app but unfortinately i didnt have a computer at home that would allow me to do that, but now that i have a laptop i will try and get back into it. Even though i did not have a computer i always brainstormed the app that i would like to make." "Did not really like the idea" "Didn't have the time + half of my team left for college + started a new one for technovation challenge 2013" "For at least a month with team members and started new apps over the summer. It was just for fun so when real work came I had to stop." "I finished fixing the bugs and we stopped evade there was no motivation or any drive behind it. We kinda lost hope and I kinda felt like I was the only person working on it. Nobody was helping me and some people in my group weren't even disappointed when we didnt get into the finals" "I stopped, because I never had much time to work on it - I was too busy with school and other things." "I was discouraged after losing the challenge." "I worked on it for the next year or so until it was released on the app store, but did not have time to pursue it further due to college classes" "Our group did work on the idea for a little while however, everyone either went to college or had too many extracurriculars to spend enough time on the project so, we ended everything." "Worked on it with my team for the summer after Technovation. Got pretty far, but never quite the finished application we hoped for. I stopped because of academic demands the following fall."

Responses to the item, "Do you have any other comments or suggestions about your experience with Technovation?" (*N*=117)	
High School Participants (Positive Responses)	"Technovation changed my life. This is not a cliche it really did. I am majoring in Computer science with a minor in entrepreneurship because of technovation challenge and want to work at a startup after graduating because of Technovation Challenge. I am attending Northeastern University because it not only allows but mandates me to do 6 month co-ops and work with a company in a job that would be applicable to my major. I want to do at least one of these co-ops with a start-up. I just wanted to convey how much Technovation has changed my life and I would love to help Technovation change the lives of others as well." "I would just like to sincerely thank Technovation, Iridescent, and the Office of Naval Reasearch for giving me the experience of a lifetime. Without Technovation I wouldn't be where I am today and I am in awe and admiration and inspired every day by the entire Technovation team. Thanks so much for everything. I will never forget all what Technovation did for my development as a professional person." "Technovation Challenge has been one of the most interesting programs I have been involved in, gets people thinking, motivated, and allows for a possibility to look into computer science more in depth. I am glad I was part of this program." "Awesome overall experience! I learned so much! If I had the time, I'd start one in France where I live now!" "Technovation should be at every high school especially the one's with engineering." "I really enjoyed Technovation overall. I think it gave me good experience with team projects and working on a deadline. I'm glad the program is continuing to prosper, while encouraging more women to get into entrepreneurship and technology." "Technovation was very fun. I never thought I would help create an actual functioning app." "I love techonovation and I hope to one day may an app that will be in the google play store" "Technovation was great for me. Now I'm learning C++" "I would love to have a computer science-based major and job in the future if possible. My Technovation experience only enhanced my love for computer science." "Technovation truly was an amazing experience! It helped me branch out to bigger things" "Technovation was a great experience and I an happy to hear that it has expended into the college division." "Technovation was a wonderful experience and I will definitely try to apply for the University Division this year!" "Technovation was a great opportunity! I even went with another team member to show our app in a meeting at MIT." "Technovation was a great way to allow my to expand my business interests outside of school. Thank you for the great experience!" "Technovation was an amazing experience. Thank you so much" "I would love to be a mentor!" "It was a really good learning experience." "Keep up the great work and great mentors." "Technovation Challenge was so much fun and learned so much." "Thanks for the opportunity" "this program was a great experience!" "Thank you for this opportunity. I participated in Technovation Challenge as a freshman high school student and although I did not continue to be part of the program for more years, I had a great experience." "Technovation was a really great experience! I'd love to do it again this year, but with track coming up and all the time Technovation takes, I'm not sure I should do it again this year. However, I really did enjoy it and it was a great experience!!!"

High School Participants (Mixed Responses)	"Can I please get offered an internship" "Don't use drag and drop programming. It doesn't really help people on the high school level learn to think like programmers enough. Just my personal opinion." "I appreciate being a part of Technovation and did gain some valuable skills from the practice. However, I'd like to stress the fact that I had already gotten my summer internship and taken a CS class before the competition started. Please don't treat my statistics as a way to imply that this program inspired me to become interested in technology. I am pretty disappointed in how Technovation treats its winning teams once the competition is over. Although it emphasized the fact that our application would be on the app store if we won, we haven't received much support in getting there." "I have a suggestion to increase the amount of spots for the international division, seeing that there are more groups and the ration to get in last year was ~43:1" "I'm currently working on creating the ""Enchanted Earth"" mobile app to encourage students to become environmentally-aware. I have created a prototype and hope to launch during Earth Day in April. I would love to meet with some developers/engineers to get some advice! More information about my app: http://www.ourgreengalaxy.org/app.php" "It'd be nice for the winning teams to get more help developing their app. The process has been a bit slow..." "Technovation needs more consistent judging." "The graphics on the software we used was not the most pliable. Try to maybe give more guidance on what you want from the student's app :)"