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STEM Outreach: Are We Making a Difference? A Case Study Evaluating the Science and Engineering Challenge Program

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Abstract

Science, technology, engineering, and mathematics (STEM) outreach programs aim to increase participation in STEM fields. However, the impact of these programs is rarely measured due to inherent difficulties in conducting long-term evaluations. This article presents a decadal evaluation of the Science and Engineering Challenge (SEC), an Australian STEM outreach program. From 2006 to 2015, 5,210 high school and 2,445 first-year university students were surveyed to assess whether the SEC influenced their decision to pursue STEM studies. Of the high school physics students, 51.9% reported that the SEC influenced their decision to study physics. A smaller yet significant impact was reported by chemistry (35.2%) and mathematics (32.0%) students. Further, 30.9% of university students indicated that the SEC influenced their decision to pursue a STEM degree. These findings demonstrate that long-term evaluation of outreach program effects is achievable and that outreach programs can indeed have a demonstrable impact on student career choices.

Keywords: engineering outreach, evaluation, secondary school, high school, STEM

There is widespread agreement that innovation is essential to solve global humanitarian and environmental issues, drive economic growth, and maintain living standards typical in developed countries (Deloitte Access Economics, 2019; Henriksen, 2012; Marginson et al., 2013). Many governments recognize the importance of science, technology, engineering, and mathematics (STEM) for driving innovation (Australian Industry Group, 2015; OECD, 2012). However, despite this awareness, many countries are facing a shortage of STEM-skilled employees (Engineers Australia, 2019; Henriksen, 2012; Plotkowski, 2012; Wang & Degol, 2013).

In an effort to mitigate these shortages, governments, private providers, industry groups, and universities internationally have developed and implemented a wide range of STEM outreach programs for young people (OECD, 2012; Sadler et al., 2018). These programs, formally defined by Vennix et al. (2017) as the delivery of educational STEM-based activities to K-12 students (and their teachers) by STEM-based organizations, have proliferated at such a dramatic rate that more than 250 can now be found in Australia alone (Commonwealth of Australia, 2016). Although the end goal of STEM outreach is to increase the number of students pursing STEM careers, individual programs often focus on diverse aspects of STEM, such as scientific literacy support for students, STEM-based pedagogy assistance for teachers, encouragement for underrepresented minority groups to pursue STEM careers, and providing exciting learning opportunities that are not usually available in schools for students (Australian Government Chief Scientist, 2016; Carpenter, 2015; Dabney et al., 2012; Illingworth et al., 2015; Jeffers et al., 2004; Kong et al., 2014; Markowitz, 2004; Şentürk & Özdemir, 2014; Vennix et al., 2017).

Challenges in Evaluating STEM Outreach

Despite ongoing heavy investment in outreach and claims that without these programs there would be greater shortages of STEM-skilled professionals than currently projected, examinations of the long-term outcomes of STEM outreach programs are largely absent in the literature (Bogue et al., 2013; Husher, 2010; Inspiring Australia Expert Working Group, 2011; Sadler et al., 2018). These long-term examinations are arguably one of the few methods available to ascertain whether outreach has an impact beyond initial enjoyment of specific programs (Todeschini & Demetry, 2017).

When evaluation of specific STEM outreach programs does occur, results are largely favorable; however, such studies tend to measure short-term changes in the attitudes and knowledge of different stakeholders such as teachers, students, or carers, rather than evaluating long-term outcomes or demonstrable causal relationships (van den Hurk et al., 2019). One reason for this might be that outreach programs are, quite simply, difficult to evaluate (Plotkowski, 2012). Sadler et al. (2018) interviewed staff members involved in various STEM outreach efforts at Australian universities who highlighted factors that present obstacles to STEM outreach evaluation, such as a lack of time and resources, particularly for long-term evaluation, which can be extremely costly, as well as the difficulty in accurately measuring changes in student aspirations. In addition, nonrandom allocation of students to outreach programs, for financial or program-specific reasons, often makes control groups unfeasible, meaning that causal inferences about the effectiveness of programs can rarely be made (van den Hurk et al., 2019).

As a result of these difficulties, short-term assessments, occurring immediately after STEM outreach programs and events have been run, and often focusing on measures other than student aspirations, are popular methods of evaluation. These evaluations typically use pre- and postprogram surveys and focus on outcomes such as general student enjoyment of the program or the perspectives of stakeholders involved in delivering programs (Carpenter, 2015; Forbes & Skamp, 2013; Laursen et al., 2007; Rennie, 2012; Sheehan & Mosse, 2013), as well as student perceptions of specific program activities (Falk & Storksdieck, 2005; Şentürk & Özdemir, 2014; Vennix et al., 2017). Relatively few focus on evaluating student aspirations for STEM education and careers. Those that do so, however, generally report positive outcomes. For example, Chalmers et al. (2014) reported that 94.4% of surveyed participants would consider studying STEM subjects in the future due to their participation in the Robotics@QUT program. Similarly, Illingworth et al. (2015) found that, after attending a one-day university-based event, students reported being 46% more likely to pursue a career in science. However, given that these surveys were taken immediately after participation in the program, long-term benefits to students' aspirations (resulting in post-compulsory STEM participation), as is the overall goal of STEM outreach, cannot be assured.

Correlational studies between general participation in out-of-school science activities and interest in STEM subjects and careers are the most popular long-term methods of STEM program evaluation (e.g., Dabney et al., 2012; Henriksen et al., 2015; Kong et al., 2014; Lyons & Quinn, 2013; Whiteley & Porter, 1998). These studies also typically reveal positive results, but they cannot draw conclusions about the effectiveness of specific programs. Dabney et al. (2012) provided one example of this type of study, finding that U.S. university students who reported having participated in science clubs and competitions at least a few times a year during secondary school were 1.5 times more likely to report interest in pursuing STEM careers after university. Similarly, in a survey of Australian university students studying science, technology, and engineering, 25% rated STEM outreach as an important or very important factor when choosing their course (Lyons & Quinn, 2013).

Three studies that focus on specific programs and examine their impact on long-term student career and study decisions are those by Bogue et al. (2013), Markowitz (2004), and Husher (2010). To assess the efficacy of an engineering summer camp in the United States, Bogue et al. (2013) used pre- and postsurveys coupled with university admission data. They found that although 13 of the 15 senior secondary students surveyed indicated immediately postcamp that they wanted to study engineering at the organizing university, only two later enrolled. These findings highlight the limitations of evaluations occurring immediately after an intervention alone. However, it is important to note that this study relied on a small sample size and limited data; it is possible that the participants enrolled in engineering at a different university. Markowitz (2004) utilized a survey to retrospectively measure the influence of a summer science camp on students' desire to pursue a STEM career. Camp participants were surveyed between 1 and 7 years postparticipation. Of the 98 participants who responded, 80% indicated that participation in the camp contributed to their interest in a science career; however, as analysis involved grouping all students (1–7 years after their participation), it is unclear whether this percentage differs for students at different time points after their participation in the program.

Husher (2010) performed both short- and long-term preliminary evaluation of the outreach program under evaluation in this article, the Science and Engineering Challenge (SEC). Surveys were administered by Husher prior to, 2 weeks after, and 12 months after participation. In addition, post-only surveys were administered to older cohorts of students 24 months and at least 36 months after participation in the program. Survey responses (N = 252) revealed that 2 weeks after participation 91% of students felt that the SEC was a worthwhile experience, and most students felt that the program had provided them with a better understanding of what scientists and engineers do. No significant difference was noted between these responses and those obtained one year later. Additionally, approximately 30% of students surveyed after 2 weeks, 12 months, and 24 months indicated that participation in the SEC influenced their intention or decision to study physics or mathematics in senior secondary school; a smaller proportion, approximately 15%, indicated the same for chemistry. Of university students surveyed, 34% and 14% of those who had participated in the SEC indicated that the program had influenced their decision to study senior high school science and mathematics subjects, respectively. Further, approximately one third of university students surveyed who had participated in the program retrospectively identified the SEC as a factor that influenced their decision to pursue university and/or undertake their current STEM degree. Although these findings were very positive, they relied on data from relatively small samples; n = 69, 49, and 109 for the 12-month, 24-month, and university student surveys, respectively. This article extends this data, using 10 years of survey information to overcome this limitation.

Overall, the influence of specific STEM outreach programs on students' decisions to pursue STEM study and careers long-term still remains largely unclear due to the lack of studies directly addressing these outcomes. This article aims to address these outcomes by conducting a long-term evaluation of a particular STEM program, the SEC. Such individual program evaluations are important, given the proliferation of STEM programs worldwide. The evaluation draws upon similar methodologies to that employed by Bogue et al. (2013) and Markowitz (2004), and builds upon the previous study by Husher (2010), to provide meaningful information about the potential long-term impacts of individual STEM outreach activities.

The Science and Engineering Challenge

The SEC is a STEM outreach program founded by the University of Newcastle, Australia, in the year 2000, consistent with its mission: "Through the provision of meaningful, hands-on experiences we aim to inspire more young people to make a difference in the world by choosing a career in science and engineering." The SEC is a competitive, workshop-based program that offers Year 9 and 10 students an immersive, practical experience that demonstrates what it would be like to work in STEM occupations. The SEC aims to achieve its mission by providing students with an opportunity to compete in engaging STEM activities that are specifically designed to have multiple correct solutions; are hands-on; and require innovation, creativity, problem solving, and teamwork to achieve success.

The SEC works alongside local organizing committees—composed of representatives from Rotary International, local universities, local schools, and many other not-for-profit, government, and industry groups—to deliver centrally located one-day events that may be attended by up to eight school teams, each represented by up to 32 students. These students work in teams of three or four, competing in either two half-day activities or one whole-day activity. Activities include building a balsa bridge and testing its weight-bearing capacity, designing and racing a small-model hovercraft, or building a functional prosthetic hand from supplies including straws and string. The SEC competition has three levels. At a regional challenge day, described above, each individual team's score contributes to their school's overall score. The top-scoring schools progress to the next stage of the competition, the Super Challenge state final. At the Super Challenge, schools from multiple regions compete against each other to represent their state at the National Final, an annual event held at a nominated venue.

This study aims to compare the findings reported by Husher (2010) to those obtained from surveys, administered to high school and university students over a 10-year period for quality assurance purposes, to answer the research question: Does participation in the SEC influence students' decisions to study STEM subjects in senior secondary school or STEM degrees at university? Given the identified need for greater representation of both women (Lyons & Quinn, 2013; Nadelson & Callahan, 2011) and ATSI (Aboriginal and Torres Strait Islander) peoples (Marginson et al., 2013) in STEM fields, we have, where possible, considered student responses not only as an entire cohort but also for male and female and for ATSI and non-ATSI students separately. Although the SEC does not specifically aim to attract female and ATSI students into the STEM pipeline, the impact of the program on these students is very important, given the disparities in their STEM participation.

Method

The evaluation draws on data obtained from two different retrospective questionnaires. Approval to utilize data from both surveys for secondary analysis was obtained from the University of Newcastle's Human Research Ethics Committee (HREC). Both surveys were designed specifically to be noninvasive and to maintain respondent anonymity. As explored in the literature review, analysis of data obtained from retrospective questionnaires has been utilized in similar studies, such as those by Dabney et al. (2012), Kong et al. (2014), and Lyons and Quinn (2013) to examine the self-reported influences of exposure to general and specific STEM outreach programs on student interest in, or decision to study, STEM.

Survey Instruments and Sample

Survey 1

The first questionnaire (Appendix A) utilized for evaluation is the High School Student Survey (HSSS). The HSSS is a retrospective postprogram questionnaire administered directly by the SEC as a measure of program performance. The HSSS was administered from 2006 onward to Year 11 and 12 students studying physics, chemistry, or mathematics (the enabling STEM subjects) who had chosen their Year 11 and 12 courses at least one year beforehand, and who had participated in the SEC in the previous 2 calendar years. Prior to 2010 the surveys were paper based, and they were distributed by the teachers to Year 11 students only, so there was no question relating to year level. After that year, the survey was web based and open to a greater cohort of students. Of the 5,210 students surveyed, 95.5% were Year 11 (comprising 3,538 paper-based respondents and 1,439 web-based respondents), and 233 were Year 12 (solely from the web-based survey). The HSSS gathers information on enrollment in science subjects and whether the SEC influenced students' decisions to study these subjects. Further, the survey asks if students found the SEC rewarding and if they had gained career/course information from their participation.

In total, 5,210 students completed the survey. The only demographic information obtained by the survey is year level and gender. In regard to gender, 54.4% were male and 45.5% were female; only 0.1% chose not to specify gender. Most students were enrolled in multiple enabling subjects, with 96% of students enrolled in mathematics, 65.6% in chemistry, and 59.7% in physics. It is important to point out that in New South Wales, where most responses came from, mathematics is not compulsory in the senior years (Years 11 and 12). It is also of note that overall enrollment of senior secondary school students in these subjects is significantly lower than enrollment of the respondents of Survey 1. In 2017, for example, mathematics enrollments in Year 12 were 72%, in physics 13%, and in chemistry 15% (Jaremus et al., 2019).

Survey 2

The second set of data was obtained from the University of Newcastle's (UON) Commencing Student Survey (CSS; Appendix B), an online long-term ex post questionnaire that directly asked all newly enrolled UON students whether the Science and Engineering Challenge had impacted their tertiary study decisions, including choice of degree and university. This survey is administered by the university, and student demographic data were obtained from their enrollment records. The survey collected data indicating the impact of participation in the SEC on study decisions at three levels:

1. the influence on Year 11 and 12 subject choices,
2. the students' decision to study at the UON, and finally
3. whether the SEC influenced students' decision to pursue tertiary study in STEM fields.

The survey was offered to students electronically on an opt-in basis in the years 2010, 2012, and 2015. The average response rate over these 3 years was 25.1%. A total of 2,445 students completed the survey. A large proportion of the survey respondents were female (71%). Students from ATSI backgrounds were well represented, with 2.4% of respondents identifying as such. The proportion of students who identified as ATSI is close to the overall proportion in the Australian population, which was 3% at the 2015 Australian census (Australian Institute of Health and Welfare, 2015). The university that hosts the SEC has a focus on providing access to tertiary studies to students from nontraditional backgrounds, which includes non-English speaking background (NESB, 12.03% of 2016 undergraduate enrollments) and ATSI students (3.57% of 2016 undergraduate enrollments). It must also be noted that 1.7% of respondents identified as NESB, but 1.8% of responding students did not specify NESB or ESB status.

Students surveyed were commencing degrees in a variety of departments (in Australia known as faculties). The Faculties of Science and IT, Engineering, and Health, all of which have strong foundations in STEM, made up 19.1%, 10.1%, and 24.0% respectively of the total student responses. The Faculty of Education and Arts made up 37.1% of the total cohort, and the rest were enrolled in the Faculty of Business and Law. For comparison purposes, Table 1 shows the percentages of enrollments per faculty at the university in the 3 years when the survey took place.

Analysis

A significance level of less than 5% ($p < .05$), was considered statistically significant for both survey analyses. Of note, it was not feasible to have a control group for either survey analysis, as both refer to questions that were relevant only for students who had attended the SEC.

Survey 1

Yearly data obtained from the HSSS were amalgamated in the SPSS statistical software program and cleaned to remove responses from students who had not attended the SEC. These students were removed because they were unable to answer questions about the SEC due to their nonparticipation. Three analyses were then conducted with the survey data. First, the question of whether students found the SEC rewarding was examined to determine the proportion of students overall, and from each demographic group, who agreed. The statistical significance of these proportions was examined using the Pearson chi-square nonparametric test, with the expected frequency of positive responses being zero. A nonparametric test was chosen since our aim was to test group differences when the dependent variable is measured at a nominal level (McHugh, 2013). Second, analysis of the self-reported influence of the SEC on

Table 1. Total Enrollments at UON

% Enrollments per Faculty	2010	2012	2015
Business and Law	16%	15%	15%
Engineering	13%	14%	14%
Education and Arts	33%	30%	27%
Health and Medicine	19%	21%	23%
Science and IT	19%	20%	21%
Total	**8,364**	**8,577**	**8,388**

the decision to study physics, mathematics, or chemistry was undertaken. For students who reported studying each subject, a contingency table was developed using the custom table tool in SPSS. The influence of the SEC on student decisions was examined by gender for each cohort that the HSSS was administered to. The percentages of male and female students who felt that the SEC had influenced their decision to study mathematics, physics, or chemistry were graphed and linear trends generated.

Finally, extended responses to open questions were analyzed in NVivo. Each statement was coded inductively into one or more discrete categories.

Survey 2

Three analyses were conducted after cleaning data in the same fashion as for Survey 1, removing students who did not participate in the SEC. First, the question of whether the SEC had influenced the university students' subject choices in senior secondary school was examined to determine the overall proportion of students who agreed, as well as any differences between genders, ATSI and non-ATSI students, and NESB and ESB students. The statistical significance of these proportions was examined using the Pearson chi-square nonparametric test, with the expected frequency of positive responses being zero (as our null hypothesis was that no students were influenced by the SEC).

Second, the influence of the SEC on a student's decision to enroll at the University of Newcastle was examined using the Pearson chi-square test in SPSS. Examination of the influence of the SEC on the decision to study science or engineering at the university level was examined first for the whole data set, and then by the faculty in which students were enrolled. The proportion of students who responded positively in each faculty were compared using z-tests, where each test was adjusted for all pairwise comparisons using the Bonferroni correction. The null hypothesis was that all faculties would have an equal proportion of students responding that the SEC influenced their decision. Responses to this question were further examined by gender and by whether students identified as ATSI or NESB.

Finally, extended responses to open questions were analyzed in NVivo. Each statement was coded inductively into one or more discrete categories.

Results

High School Student Survey

In this section we present a summary of relevant data from the Survey 1 (see Table 2) as well as a detailed analysis of associations between the different variables.

Of the students who responded that they were enrolled in physics, 1,534 indicated that participation in the SEC had influenced their decision to take this course in senior high school. This amounts to 51.9% of students studying physics (59.1 = 29.4/[29.4 + 27.2]) and is a statistically significant proportion, X^2 (1, N = 2,936) = 5.31, p = .021. Examination of the positive response rates by gender revealed that 54% of female students and 50% of male students who had chosen to study physics identified the SEC as an influencing factor. The difference in positive response rate between genders was statistically significant, X^2 (1, N = 2,936) = 4.95, p = .026. Figure 1 illustrates the percentage of students who responded "yes" to the question "Did the SEC influence your decision to study physics?" by calendar year. Linear regression modeling of the positive response rate was carried out separately for male and female cohorts by year, revealing positive trends for both genders. R^2 values for the two regression models were 0.1522 and 0.6899 for female and male physics students, respectively.

Of students enrolled in chemistry (n = 3,259), 35.2% responded positively to the question "Did the SEC influence your decision to study chemistry?" Females were more likely to indicate that the SEC influenced them to study chemistry in senior high school. Positive responses by gender for each year are shown in Figure 2. Overall, 33% of male senior high school chemistry students who responded to the survey indicated that the SEC influenced their decision to take this subject. This was the case for 38% of female chemistry students. Again, this difference was statistically significant, X^2 (1, N = 3,259) = 7.22, p = .007. Examination of responses to this question by year cohort indicates that there has been little change in the proportion of female students influenced by the SEC to take chemistry over time. There is, however, an increasing trend in the number of male students who identified program participation

Table 2. High School Student Survey Summary

		Frequency	Percent
Gender	Male	2,833	54.4
	Female	2,371	45.6
Did the SEC provide appreciation of STEM careers?	Yes	3,396	65.2
	No	699	13.4
	System Missing*	1,115	21.4
Did the SEC influence your decision to study physics?	Yes	1,534	29.4
	No	1,419	27.2
	System Missing*	2,257	43.4
Did the SEC influence your decision to study chemistry?	Yes	1,148	22.0
	No	2,115	40.6
	System Missing*	1,947	37.4
Did the SEC influence your decision to study mathematics?	Yes	1,560	29.9
	No	3,304	63.4
	System Missing*	346	6.7
Did the SEC provide appreciation of science and engineering courses?	Yes	982	18.8
	No	88	1.7
	System Missing*	4,140	79.5

** System Missing items indicate students who did not complete the question because they were not studying physics/chemistry/mathematics/science and engineering, respectively, in Year 11.*

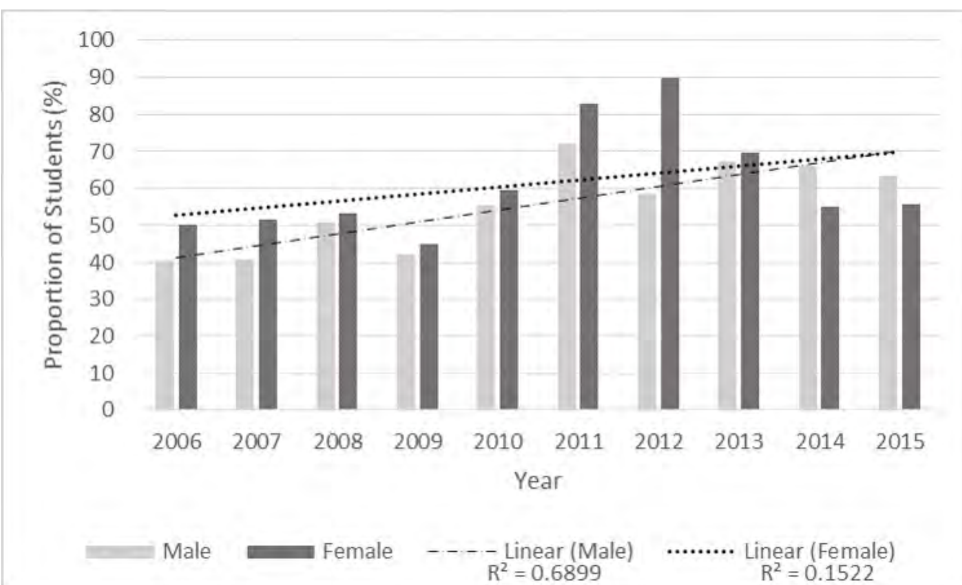

Figure 1. Students Influenced by SEC to Study Physics by Gender and Calendar Year

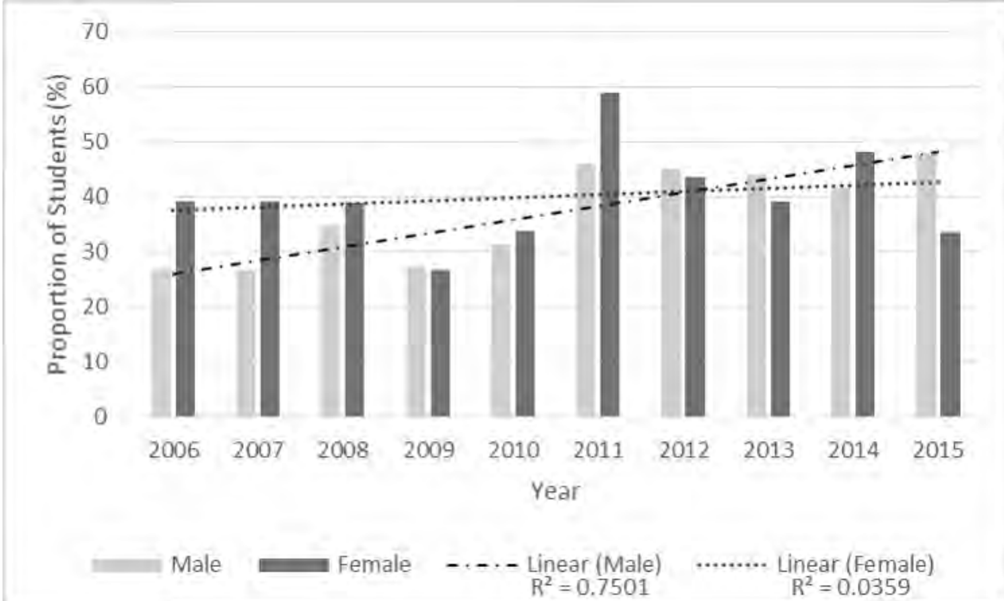

Figure 2. Students Influenced by SEC Participation to Study Chemistry by Gender and Calendar

as a factor that influenced their decision to study chemistry. It should be noted that the R^2 values for the generated linear regression models for male and female students were 0.7501 and 0.0359, respectively.

Of the students enrolled in mathematics, 32% indicated that participation in the SEC influenced their decision to take this subject in senior high school. This proportion of students is statistically significant, X^2 (1, N = 4,858) = 624.14, $p < .000$. Unlike students enrolled in chemistry and physics, there was no statistically significant difference in rate of positive responses between males and females, X^2 (1, N = 4,858) = 0.80, p = .365. Yearly positive response rates for male and female students are shown in Figure 3. It should be noted that in 2011 a large proportion of students, 53%, identified participation in the SEC as influential in their decision to study mathematics.

Students found the SEC rewarding, with 92.9% responding positively. This proportion, when tested using the Pearson chi-square nonparametric test, was statistically significant, X^2 (1, N = 5,184) = 3813.06, $p < .000$. Further, students surveyed from 2006 to 2011 inclusive were asked whether they felt that the SEC provided information about "the practical aspects of science and engineering careers." In total, 83% of students who answered this question responded positively, and this response was statistically significant, X^2 (1, N = 4,095) = 1776.27, $p < .000$. There was no significant difference between the proportion of male and female students who felt the SEC program offered an understanding of science and engineering careers (p = .959). From 2012 onward (n = 1,070), students were instead asked if the SEC program provided them with an "appreciation of the practical aspects of science and engineering courses." Here, 92% of students responded positively, a statistically significant proportion, X^2 (1, N = 1,070) = 746.95, $p < .000$. Again, there was no significant difference between the proportion of male and female students who felt that they had gained valuable information regarding science and engineering courses from SEC attendance (p = 0.216).

Student responses to the open-ended question "Do you have any comments to make about your experiences with the Science and Engineering Challenge?" were largely positive, with 1,113 comments coded as positive and 84 as either negative or neutral. Student comments were further analyzed and classified by theme. The majority of comments were about student enjoyment of the SEC program. The top five identified themes were enjoyment (n = 343), informative/learning experience (n = 179), constructive criticism of the program (n = 116), rewarding experience (n = 107), and positive effect on career/study choices (n = 93).

Specific examination of comments relating to career or study choices shows that

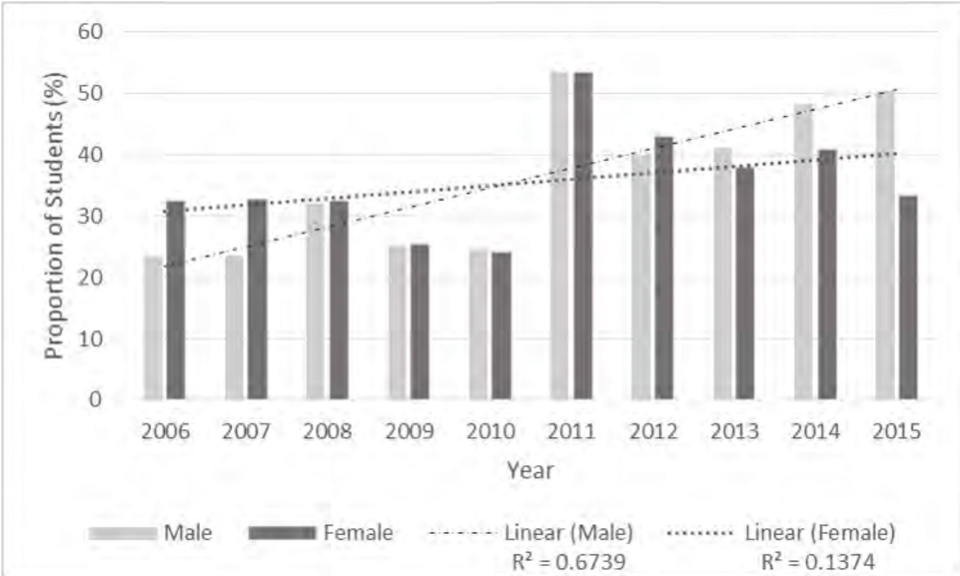

Figure 3. Students Influenced by SEC Participation to Study Mathematics by Gender and Calendar

students more often identified a positive effect than no effect. In fact, a positive effect was identified in 92 student responses, whereas no effect was identified by 33 students. Examples of comments that indicated a positive effect included "[the SEC] made me want to learn more in Math and Chemistry and Physics," "[the SEC] was very influential towards my decision to take up Chemistry," and "[the SEC] made me realise I want to be an engineer."

The UON Commencing Student Survey

In this section we present a summary of relevant data from the survey (see Table 3) as well as a detailed analysis of associations between the different variables.

Of the students who participated in the CSS, 458 (18.7%) had participated in the SEC program during high school; the remainder had either not participated or were unable to recall. It should be noted that survey participation was voluntary, and the average response rate was 25.1%; the number of commencing students who had participated in the SEC was approximately 1,800. Examination of student proportions from each faculty (Figure 4) revealed a greater proportion of students enrolled in the Engineering faculty (31%) that had attended the SEC than in any other faculty. This difference was statistically significant, X^2 (1, N = 1,070) = 746.95, p < .000. Furthermore, there was a statistically significant greater proportion of students who had attended the SEC enrolled in the Engineering, Science and IT, and Health faculties than in the Business and Law and Education and Arts faculties, X^2 (1, N = 2,445) = 10.60, p = .001. Across the faculties there was no statistically significant difference between the proportion of students who did or did not recall whether they had attended the SEC during high school (p > .05). Statistical significance was determined by comparing column proportions in a custom table and adjusted for all pairwise comparisons using the Bonferroni correction.

Of the students who had attended the SEC, 37.8% indicated that this outreach program had influenced which subjects they selected to study in their senior high school years. This proportion was statistically significant, X^2 (1, N = 458) = 27.39, p < .000. This influence was observed equally among ATSI and non-ATSI, as well as NESB and ESB students (p = .92 and p = .27, respectively). Not surprisingly, students enrolled in the Business and Law faculty were the least likely to indicate that participation in the SEC had influenced their subject decisions in senior high school. Students enrolled in the Faculty of Engineering as well as the Faculty of Health were the most likely to say that participation in the SEC had impacted their senior high school subject selections, with 51% and 43% of students, respectively, indicating as such.

The SEC had a lesser, but still statistically significant, impact on commencing stu-

Table 3. UON Commencing Student Survey Summary

		Frequency	Percent
Gender	**Male**	709	29.0
	Female	1,736	71.0
Aboriginal or Torres Strait Islander Status	**ATSI**	59	2.4
	Not ATSI	2,386	97.6
NESB status	**NESB**	41	1.7
	Non-NESB	2,361	96.6
	Not disclosed	43	1.7
Participation in SEC	**Yes**	458	18.7
	No	1,755	71.8
	Don't Remember	232	9.5
Did participation in SEC influence senior study decisions?	**Yes**	173	7.1
	No	285	11.7
	System Missing*	1,987	81.3
Did participation in SEC influence decision to study science or engineering?	**Yes**	88	3.6
	No	370	15.1
	System Missing*	1,987	81.3

** System Missing items indicate students who did not complete the question because they had not participated in the SEC.*

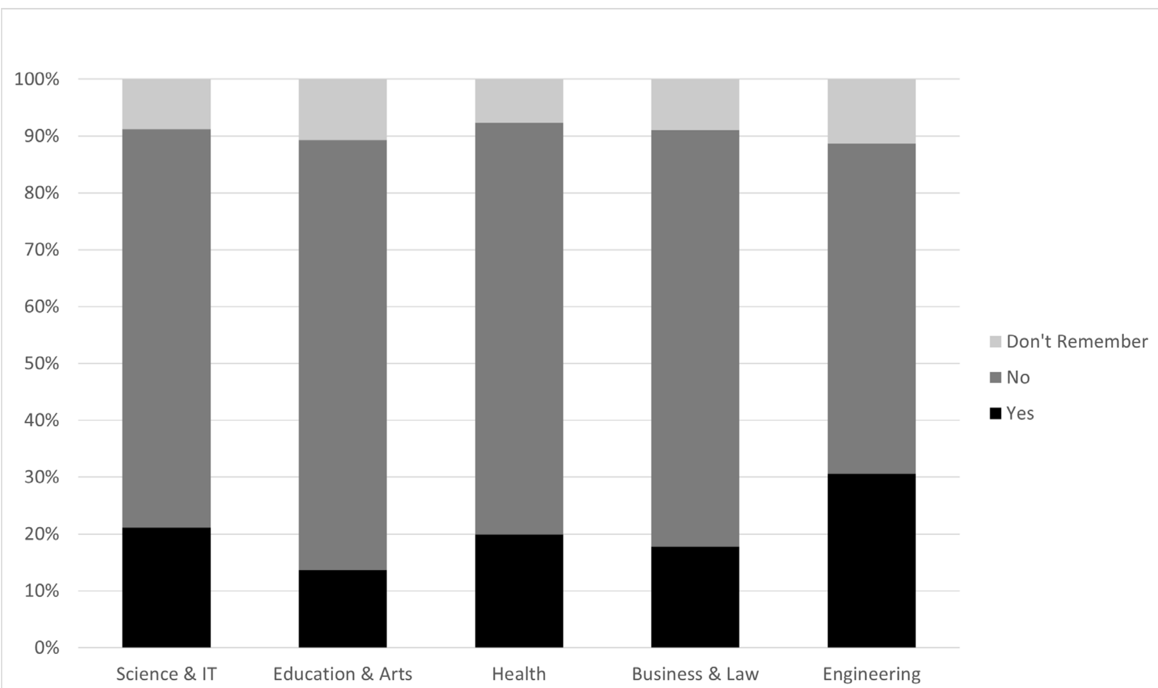

Figure 4. Proportion of Students Who Had Participated in the SEC During High School by Faculty

dents' decision to study specifically at the UON, with 21.6% acknowledging an effect, X^2 (1, N = 458) = 147.60, p < .000. The SEC had a greater influence on students' decision to study science and engineering courses at a university level. In fact, students enrolled in the Science and IT, Health, and Engineering faculties indicated that this was the case. This proportion was statistically significant, X^2 (1, N = 458) = 8.69, p = .003.

Further examination of student responses to the question regarding the influence of the SEC revealed that a greater proportion of students responding positively (46%) were enrolled in the Faculty of Engineering. Comparison of responses regarding influence to study science and engineering at university level by gender revealed a greater proportion of positive responses among male students, X^2 (1, N = 458) = 9.30, p = .002. Male students were more than 1.5 times more likely to identify the SEC as influencing their decision to study science or engineering at university.

Student responses to the open question "Is there anything else you would like to tell us about how the Science and Engineering Challenge affected your decisions about your career or study options?" were coded inductively for common themes. The most frequently identified theme was enjoyment, with 40% of comments including this theme (n = 48 out of 114). Such comments included "seeing the physical application made it seem more interesting to study such courses," "[the SEC] was an EXCELLENT opportunity for applying practical experience and really engaged me in science," and "[the SEC] made me realise how much I enjoy the construction process." The next most populated categories were positive impact on career or study, followed by no impact on study or career. Only one student commented that participation in the SEC program had a negative impact on his/her decisions about career or study.

Discussion

Many student responses to both surveys indicated that participation in the SEC had a positive influence, initially on high school subject selection, and subsequently on degree selection at university. Surveying students one year, and then at least 3 years after participation, enabled the measurement of self-reported outcomes rather than aspirations. Further, the results of this study corroborate, and in some cases surpass, those presented by Husher (2010), who examined the efficacy of the SEC at an earlier stage in its evolution using a smaller sample.

High School Subject Selection

Of the students who participated in the HSSS and were enrolled in either physics, chemistry, or mathematics, 51.9%, 35.2%, and 32.0%, respectively, reported that their decision to study these subjects in senior high school was influenced by participation in the SEC. These proportions of students are notably higher than the proportions reported by Husher (2010), who found, 12 months after participation, that 36.2%, 11.8%, and 20.6% of students self-reported that the SEC influenced their decision to enroll in physics, chemistry, and maths (general and advanced), respectively.

Interestingly, both the results of the present study and those presented by Husher (2010) showed that students enrolled in physics were more likely to indicate that the SEC influenced their subject selection than those enrolled in mathematics or chemistry. This correlates with the learning environment presented by the SEC, where many of the activities have a strong focus on engineering and physics.

When first-year university students were surveyed in the CSS, 37.8% responded that participation in the SEC had influenced their subject selection in senior high school. Not only was this proportion statistically significant (p < .05), it was also similar to the proportion of high school students who had indicated that the SEC had influenced their decision to study chemistry or mathematics. This suggests that the influence of SEC participation remains not just 12 months after participation, but 3 or more years later when students have enrolled at university. These results support those previously reported where 34% of surveyed first-year undergraduate students reported that participation in the SEC influenced their decision to study science in senior high school (Husher, 2010).

Similarly, an independent study of the opinions of Queensland school students revealed that although personal factors and social factors were the most influential in Year 11 and 12 subject selection, participation in extracurricular activities played an important role during the early stages of subject selection (Whiteley & Porter, 1998). Internationally, studies have also identified extracurricular activities as playing an important role in student decision-making, particularly in relation to the selection of STEM subjects (Henriksen, 2012; Henriksen et al., 2015). Compared to the 80% of summer science camp participants surveyed by Markowitz (2004) who indicated that the camp had contributed to their subsequent pursuit of a science career, the proportion of university students who responded that the SEC had influenced their decision to undertake a STEM degree is much smaller. However, comparison between these two studies should be viewed with caution as the studies had vastly different sample sizes and are very different. The program evaluated by Markowitz was a merit-based summer camp that focused specifically on science, and therefore presented a very different learning environment from the SEC. In addition, Henriksen et al. (2015) found that targeted STEM recruitment programs affiliated with universities had the greatest impact on study decisions when participation coincided with major educational decision points. This suggests that the SEC could have a greater impact on the senior subject selection of students who attended in Year 10 rather than Year 9.

STEM Degree Selection

A statistically significant number of students who were enrolled in the Faculties of Engineering or Science and IT indicated that participation in the SEC during high school had later influenced their decision to study in these disciplines. In fact, the proportion of students who responded this way (30.9%) was similar to the one third of students who self-reported that the SEC influenced them to undertake study in their current STEM degree in Husher's (2010) earlier study. This is slightly higher than the proportion of students, 25%, who identified STEM outreach programs as an important or very important factor in educational decision-making in a study of Australian university students by Lyons and Quinn (2013).

These figures indicate that, of students who participated in the SEC and subsequently pursued further study in STEM fields (whether in senior high school or at university), approximately one in three identified the SEC as a factor that influenced their study choices.

Examination of HSSS results highlighted the role of the SEC in providing career and study information. An overwhelming majority of students indicated that the SEC provided information not only about the practical aspects of science and engineering courses at university (92%), but also about subsequent careers (83%). Furthermore, examination of student responses to the open-ended question revealed that a substantial number of students (n = 92) expressed—in their own words—that the SEC influenced their study and career decisions. This number is approximately three times the number of students whose responses indicated that the SEC did not affect their career or study choices. A similar trend was observed in the comparable open-ended question in the CSS, where the second most common theme was the positive impact of the SEC on study and career choices. Together, this information suggests that the SEC may provide career information in a format that is accessible and understandable for most participating students and that this information influences a significant proportion of these students to further pursue STEM study and careers. It is very difficult to ascertain whether these students would have chosen a STEM degree if they had not participated in the SEC. However, their specific mention of this outreach program as an influence in their decision indicates that at least they recognized it several years after their participation as something they enjoyed and somewhat affecting their career path.

The self-reported influence of the SEC is representative of the positive correlation between attending STEM outreach events and increased student knowledge of and interest in STEM careers reported in the literature. For example, Dabney et al. (2012) contended that students who participated in STEM outreach were, on average, 1.5 times more likely to demonstrate interest in STEM-related careers than students who did not participate in these activities. Another study that evaluated the impact of a single STEM outreach activity, the NSEW Science Extravaganza in Manchester, found that when asked, 82% of students said that the event provided them with information about STEM-related university degrees, and 46% claimed that their participation increased their interest in pursuing a STEM career (Illingworth et al., 2015).

The SEC and Groups Underrepresented in STEM

Comparison of positive response rates (indicating that SEC participation had influenced senior high school subject selection) between male and female students revealed a notable difference. Overall, female chemistry and physics students were more likely to identify the SEC as a factor that encouraged them to study these subjects in senior high school. This finding is similar to that from previous research by Nadelson and Callahan (2011), who found that female secondary students were more likely to be positively influenced by science outreach programs.

It is clear from our analyses that earlier instances of the SEC were more successful at encouraging female than male participation in senior STEM subjects; however, this difference is less evident in more recent years. For both chemistry and physics, the linear trends generated were more descriptive of the variation in positive response rate for males. We speculate that a more comprehensive STEM outreach environment targeting young women means that the SEC may no longer be the first experience of nonschool STEM for female students, particularly in rural and remote areas.

The gender difference in the likelihood of the SEC influencing decisions to pursue STEM subjects and careers is not evident when students commence tertiary studies. The CSS results indicated that of those students studying in STEM faculties, there was no statistically significant difference between the proportion of male and female students who identified the SEC as an influential factor in their degree selection. This is consistent with findings from surveying students enrolled in science, technology, and engineering degrees across 29 Australian universities, where females were no more likely to identify STEM outreach programs as influential than their male counterparts (Lyons & Quinn, 2013).

The CSS showed that there was no significant difference between response rates of ATSI and non-ATSI students to questions regarding whether participation in the SEC influenced either senior high school subject selection or further study of science or engineering at university. Although the SEC does not specifically aim to increase STEM participation among ATSI students, it is deeply committed to addressing equity issues. For example, in 2015 the SEC worked with rural and remote communities, professional groups, industries, and businesses in the Northern Territory and Western Australia to set up the Australia North West Tour. This highly successful tour allowed students in remote communities like Alice Springs, Katherine, Derby, Broome, Port Headland, Tom Price, and Karratha to participate in the SEC. Across this tour an average of 22%, and as high as 68% in one remote region, of the 1,780 participating students identified as ATSI.

Limitations

The design of the surveys used in the study provided a few challenges for data analysis and interpretation. The survey, designed for quality assurance rather than research, included leading questions. The decision to phrase questions in this way was made to simplify the coding process rather than to solicit favorable results. Students may have felt that it would be perceived favorably by the university to answer positively about their enjoyment and the career influence of the SEC.

The response rate among students for the HSSS could not be determined. It is estimated that over 150,000 high school students participated in SEC events between 2006 and 2015, but only 5,210 students (3.5%) responded to the survey. It is unclear how many students were afforded the opportunity to complete the survey, as distribution required cooperation from teachers and principals 12 months or more after participation in the SEC. Perhaps students who completed the HSSS survey did so because they felt more positively about their participation in the SEC. Another mitigating factor to consider was that the HSSS survey was taken 12 months after participation, so some students may have changed schools in this time and therefore not had the opportunity to participate in the HSSS. The average response rate for the CSS was 25.1% over the 3 years. Participation in both surveys was on a voluntary basis, so nonresponse bias should be considered when interpreting the results.

Further, since primarily dichotomous questions, rather than Likert scales, were used in the surveys, there was no way to quantify the extent to which the SEC influenced students' decision to study STEM, either at university or in senior high school. For future evaluation of the SEC program, the use of scaled responses, pre- and postassessment, as well as examination of Year 11 STEM subject enrollment rates in schools that participated in the SEC, will be considered.

Conclusions

Research examining student interest and success in STEM indicates that STEM outreach programs are part of a dynamic and complex learning ecosystem in which "educators, policy makers, families, businesses, informal science institutions, afterschool and summer providers, higher education, and many others [work] towards a comprehensive vision of . . . STEM learning for all children" (Traill & Traphagen, 2015, p.1). Further, STEM outreach programs have been shown to be just one of many factors that may affect student decision-making in relation to study and career aspirations (Archer et al., 2013; Henriksen, 2012; Henriksen et al., 2015). This complex interplay between different factors makes evaluation of a single program challenging.

Although the complexity of STEM learning ecosystems presents numerous barriers to evaluation of STEM outreach programs, research in evaluability of assessment shows that it is possible to ensure that preconditions that enable evaluation of outreach programs exist (Trevisan, 2007). Indeed, outreach programs have the potential to be evaluated as long as they "assess the extent to which measurable objectives exist, whether these objectives are shared by key stakeholders, whether there is a reasonable program structure and sufficient resources to obtain the objectives, and whether program managers will use findings from evaluations" (Trevisan, 2007, p. 291). However, many outreach programs start their journeys before these considerations are put in place. The research presented in this article demonstrates that such evaluation is still possible. Here we have demonstrated that secondary analysis of retrospective survey data can be used effectively to assess the longer term self-reported impact of participation in the SEC on students' study choices. The results, although painting a very positive picture of the program, highlight areas where the evaluation could be improved. We believe our research contributes to building a knowledge base for effective evaluation of STEM outreach, which is essential not only for continued program development but to guide future investment in such programs (Devi et al., 2016).

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Appendix A

High School Student Survey (HSSS)

Have you participated in the Science and Engineering Challenge?
_____ Yes
_____ No

Are you in year 11 or 12?
_____ Yes
_____ No

If you answered YES to both of these questions, help us build a better Challenge for all students by completing this online survey—it only takes 5 minutes!

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1. Did you participate in the Science and Engineering Challenge in the last 2 years?
_____ Yes
_____ No

2. Gender
_____ Male
_____ Female

3. In which school year are you enrolled?
_____ Year 11
_____ Year 12
_____ Other (please specify)

4. Did you find the Science and Engineering Challenge a rewarding activity?
_____ Yes
_____ No
_____ Not Applicable

5. Did the Science and Engineering Challenge give you an appreciation of the practical aspects of science and engineering courses?
_____ Yes
_____ No
_____ Not Applicable

6. Are you currently enrolled in the following?

	Yes	No
a. Physics	_____	_____
b. Chemistry	_____	_____
c. Mathematics	_____	_____

7. Did the Science and Engineering Challenge influence your decision to study?

	Yes	No	Not Applicable
a. Physics	_____	_____	_____
b. Chemistry	_____	_____	_____
c. Mathematics	_____	_____	_____

8. Do you have any comments to make about your experiences with the Science and Engineering Challenge?

Thank you very much for taking the time to complete this survey.

Note that prior to 2012, Question 5 asked students whether the Science and Engineering Challenge provided them with an "appreciation of the practical aspects of science and engineering careers."

Appendix B

The University of Newcastle's Commencing Student Survey

SEC1. Did you participate in the Science and Engineering Challenge while you were at school?
_____ Yes
_____ No
_____ Don't remember

SEC2. Did your participation in the Science and Engineering Challenge influence your decision to study Physics, Chemistry or Mathematics in the final two years of secondary school?
_____ Yes
_____ No

SEC3. Did the Science and Engineering Challenge influence your decision to study at the University of Newcastle?
_____ Yes
_____ No

SEC4. Did the Science and Engineering Challenge influence your decision to study Science or Engineering at the University of Newcastle?
_____ Yes
_____ No

SEC5. Is there anything else you would like to tell us about how the Science & Engineering Challenge affected your decisions about your career or study options?