Gender Differences and The Learning Outcomes in Science Outreach
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Abstract
For the past 15 years our outreach program Elemental Expeditions (EE), has made great strides towards broadening the educational opportunities available to local elementary schools. When exposed to similar resources, females and males perform differently in factual and nonfactual subjects. Taking this into consideration, an experiment was designed using 3 different questions to measure student’s ability to recognize factual and nonfactual concepts taught during our demonstrations. Here we hypothesize that a well-executed outreach program can reduce the gap between male and female students performance. Our results show that both genders improved in the post-quiz compared to the pre-quiz. In the pre-quiz there was a statistically significant difference between the male and female scores, while in the post-quiz there was not a statistical significant difference between the male and female scores; this shows that the gap was reduced.

Introduction
Elemental Expeditions (EE) has built strong ties throughout the local community by promoting Science, Technology, Engineering, and Math education (STEM) to disadvantaged youth attending resource-limited schools through hands-on chemistry experiments and interactive lesson plans. For the past two years, EE has incorporated multiple choice pre- and post-quizzes to measure the students understanding of the concepts taught. This project was an expansion of the outreach program to compare results of female and male students in the same geographic location.

Although Male students may perform better than females in life science exams; studies show that female students do tend to get higher grades in multiple subjected tests than male students do. [2],[4]

Some of the issues related to gender bias were associated with student- teacher relationships. In our outreach program, we tried to break traditional relationships between the presenters and the students. We did this by communicating with students and asking them to participate in the presentation more so than their teacher may have.

Probably one of the reasons that males are more associated with science is that the media contacts women scientists less often than men scientists. [3] In our outreach program, 50% of the presenters were women. This was done to help change the stereotypic association of males excelling in science.

Experimental testing was completed to determine whether there was a difference between male and female students in grasping factual and non-factual concepts when comparing pre and post quizzes. And to see if we have reduced the gap between the scores of females and males by our outreach program.

The study population was 1,108 divided equally between male and female students.

Method
Target schools were contacted with information regarding the STEM outreach program and chemistry experiments. If the schools were interested, information was exchanged regarding pre- and post-quizzes, demonstration dates, and class sizes. Arrangements were made for the students
to take the pre-quiz prior to the expedition presentation. The presentations included concepts of exothermic reactions, creating polymers, static electricity, physical changes and states of matter, temperature and pressure, surface tension, acid/base chemistry, and PH indicators. These were emphasized through oral and hands on experimental demonstrations by a diverse group of presenters of both genders (50% female, 50% male) and different cultural backgrounds. In addition to these concepts, the pre- and post-assessments included nonfactual questions regarding implicit biases and factual questions regarding chemical makeup.

Several days after the expedition, reformatted versions of the pre-quiz were given to the students as a post-quiz. After both the pre- and post-quizzes were collected, the data from every quiz was entered individually. For confidentiality reasons, the quizzes were not compared on an individual basis; rather, the responses were analyzed as a whole. When analyzing the data from pre- and post-quizzes, the percentage change for each gender was calculated separately. When the difference was compared, a percentage difference was found. A two tailed t-test was paired to find p-values between all the previously described relationships. P-values smaller than 0.05 are assumed to be significant while p-values greater than 0.05 are not significant. [1]

**Results and Discussion**

Our results show that there is a significant difference between the scores of pre and post quizzes in females in question 1 and 3. In total, female students scored 14.88 out of 36 on the pre-quiz, on the post-quiz they scored 15.96 out of 36 which is a 7.29% increase with a P-value of 8.1× ́10^-3 which is significant.

Broken down, the average score of each female student on pre-quiz question 1 was 3.94 out of 12, the post quiz score was 4.47 out of 12 which shows a 13.67% increase with a P-value of 1.83× ́10^-3 which is significant. The average score on pre-quiz question 2 was 6.05 out of 12, the post quiz returned with a score of 6.28 out of 12 which shows a 3.82% increase and a P-value of 2.27× ́10^-1 which is not significant. The average score on pre-quiz question 3 was 4.9 out of 12, the post quiz was 5.21 out of 12 which shows a 6.45% increase and a P-value of 2.05× ́10^-2 which is significant. This result shows that female students improved partially on non-factual concepts and significantly on factual concepts.

Our results show that there was significant difference between the scores of males on all three tested categories. In total, male students scored 14.08 out of 36 on the pre-quiz, on the post quiz they scored 15.49 out of 36 which is a 10.01% increase with a P-value of 3.5× ́10^-4 which is statistically significant.

Broken down, the average score of each male participant for question 1 was 3.63 out of 12, the post quiz score was 4.09 out of 12 which shows a 12.67% increase with a P-value of 3.5× ́10^-3 which is statistically significant. For question 2 the average score was 5.4 out of 12 for the pre-quiz and 6.0 out of 12 for the post quiz with a 11.1% increase and a P-value of 1.79× ́10^-1 which is statistically significant. For question 3 the average pre-quiz score was 5.05 out of 12 and 5.43 out of 12 for the post quiz with a 7.58% increase and a P-value of 5.39× ́10^-3 which is statistically significant. This result shows that the male students improved in factual questions as well as non-factual questions.

Comparing pre-quizzes results of females with males, revealed that there was a difference between the answers of the students to nonfactual questions from the beginning. Overall, there was a 5.52% difference with female students having higher score than male students. Paired two tailed t-test showed that the P-Value is equal to 3.19× ́10^-2 which indicates that there is a statistically significant difference between the scores of female students and male students from the beginning.
Broken down, in question 1 which is a non-factual question, there was an 7.97% difference with female students having a higher score and the P-value of $4.11 \times 10^{-2}$ which is significant. In question 2 which is a non-factual question as well, there was a 11.29% difference with female students having higher score and the P-value of $3.0 \times 10^{-4}$ which is again statistically significant. In question 3 which is a factual question, there was a 2.98% difference with male students having the higher score and a P-value of $2.62 \times 10^{-1}$ which is not statistically significant.

The post-quizzes were compared as well. This comparison exposed that the gap between male and female students decreased. Overall, there was a 3.02% difference with female students having a higher score than male students. The paired two tailed t-test showed that the P-Value is equal to $2.68 \times 10^{-1}$ which indicates that the difference is not significant at all.

Broken down, in question 1 which is a non-factual question, there was an 8.85% difference with female students having a higher score and the p-value of $3.64 \times 10^{-2}$ which is statistically significant. In question 2 which is a non-factual question as well, there was a 4.53% difference with female students having higher score and the p-value of $1.76 \times 10^{-1}$ which is not statistically significant. In question 3 which is a factual question, there was a 4.04% difference with male students having the higher score and a P-value of $1.29 \times 10^{-1}$ which is not statistically significant.

As other studies have shown, females perform better in nonfactual concepts while males perform better in factual concepts; our data shows the same results. [1] In question 1 which is a nonfactual question, the gap between genders increased from pre- to post-quizzes with females doing better. In question 3, which is a factual question, the gap between genders increased from pre- to post-quiz with males doing better. The difference that our outreach program made was mostly in question 2 which is a nonfactual question. The gap between genders drastically decreased. This decrease resulted in the overall gap no longer being statistically significant.
Conclusion
Our results show that females were particularly better on answering non-factual questions while males were better at answering factual questions. Overall, females had higher scores than males when considering all the categories added together. In the pre-quiz there was a statistically significant difference between the male and female scores, while in the post-quiz there was not a
statistical significant difference between the male and female scores; this shows that the overall gap was reduced.

**Future work**
Elemental Expeditions will continue its outreach programs by improving on the way the experiments were taught to the children of all types of institutions and by enhancing our presence throughout the year. With the data compared between genders, we will be using different approaches and alternative experiments to try to increase female students understanding of factual concepts.

**Acknowledgement**
We wish to thank the Salt Lake Community College Chemistry Department for their support in this research. We also like to thank faculty members at Salt Lake Community College Chemistry Department specially, Ron V. Valcarce, Mary Alvarez, Peter J. Iles, Luther D. Giddings, Neil R. Bastian, Ryan Holcomb who advised and supervised this research from the beginning to the end. We would also like to thank the following students for their involvement: Brandon Powell, Jerley Burgos, Brittany Johnson, Nour Alkheishali. Our profound gratitude goes to Professor Alia Maw for conducting statistical analysis and enhancements of this research.

**References**