Getting Everyone to the Fair: Who Participates in and Benefits from Science and Engineering Fairs (Evaluation)

Dr. Joni M. Lakin, Auburn University

Joni M. Lakin, Ph.D. from The University of Iowa, is Associate Professor of Educational Foundations, Leadership, and Technology at Auburn University. Her research interests include educational assessment, educational evaluation methods, and increasing diversity in STEM fields.

Ms. Mary Lou Ewald, Auburn University

Mary Lou Ewald is the Director of Outreach for the College of Sciences and Mathematics at Auburn University. She is also the Co-PI for AU-AMSTI and the Director of the AU Science in Motion program. Prior to her current position, she served as a Science in Motion physics specialist and an Instructor of general biology courses at Auburn University. For the past 15 years, Ms. Ewald has specialized in K-12 educational program development and implementation and currently oversees an outreach staff that delivers over twenty STEM-based student programs annually, including BEST Robotics, Science Olympiad, Greater East Alabama Regional Science and Engineering Fair, Summer Science Institute, Auburn Mathematical Puzzle Challenge, AU Explore, and Science Matters. In recent years, she has focused her K-12 efforts on working with STEM faculty to create teacher professional development opportunities related to project-based learning in middle and high school classrooms. Her academic training includes a B.S. in Physics and an M.S. in Biology, both from Auburn University.

Prof. Virginia A. Davis, Auburn University

Dr.Virginia A. Davis' research is primarily focused on using fluid phase processing to assemble cylindrical nanomaterials into larger functional materials. Targeted applications include optical coatings, 3D printed structures, light-weight composites, and antimicrobial surfaces. Her national awards include selection for the Fulbright Specialist Roster (2015), the American Institute of Chemical Engineers Nanoscale Science and Engineering Forum's Young Investigator Award (2012), the Presidential Early Career Award for Scientists and Engineers (2010), and a National Science Foundation CAREER Award (2009). Her Auburn University awards include the Excellence in Faculty Outreach (2015), an Auburn University Alumni Professorship (2014), the Auburn Engineering Alumni Council Awards for Senior (2013) and Junior (2009) Faculty Research, the Faculty Women of Distinction Award (2012), and the Mark A. Spencer Creative Mentorship Award (2011). Dr. Davis is the past chair of Auburn's Women in Science and Engineering Steering Committee (WISE) and the faculty liaison to the College of Engineering's 100 Women Strong Alumnae organization which is focused on recruiting, retaining and rewarding women in engineering. She was also the founding advisor for Auburn's SHPE chapter. Dr. Davis earned her Ph.D. from Rice University in 2006 under the guidance of Professor Matteo Pasquali and the late Nobel Laureate Richard E. Smalley. Prior to attending Rice, Dr. Davis worked for eleven years in Shell Chemicals' polymer businesses in the US and Europe. Her industrial assignments included manufacturing, technical service, research, and global marketing management; all of these assignments were focused on enabling new polymer formulations to become useful consumer products.

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Science and Engineering (S&E) fairs are a valuable educational activity that are believed to increase students' engagement and learning in science and engineering by using inquiry-focused learning, engaging students in authentic scientific practices and engineering design processes [1-3], and emphasizing creativity [4, 5]. Proponents also argue that S&E fairs enhance students' interest in science and science careers [6, 7] as well as engineering [2]. From the fair, students report that they have learned more about the scientific process and engineering design, although they may not all feel their attitudes towards STEM fields has improved [2, 8]. In this paper, we focus on science attitudes, but because the fair includes engineering and the Next Generation Science Standards (which inform our state standards) incorporates engineering design practices, we feel our findings on S&E fairs will inform P-12 research on engineering education.

Despite the possible benefits, S&E fair projects are often optional and students must rely heavily on parental resources and knowledge to design a successful project [9, 10]. In the third author's experience in running a regional S&E fair, schools with higher poverty rates and fewer school resources are less likely to hold school-level fairs at all. When these schools do hold fairs and send students to the regional competition, the projects are noticeably lower in quality from students who come from better-resourced schools or who come from higher income families. The goal of the project reported on here was to expand the adoption of S&E fairs in high-poverty schools in our area of the Alabama Black Belt (a historically poor, agricultural region in central Alabama). Through professional development and goal setting with teachers, we supported teams of teachers (grades 6-12) in implementing local S&E fairs and helped them develop the knowledge and mentoring skills needed to help students create effective projects that would be of similar quality to those that advance from the regional S&E fair to state and international competitions.

Although the program strongly encouraged teachers to make projects mandatory, in order to encourage more students to engage with projects, many teachers made participation optional or only incentivized participation. As a result, we had the opportunity to explore which types of students, based on demographics, were more likely to complete projects. We were also able to explore the impacts of fair participation on students' attitudes towards science when controlling for demographic characteristics and pre-existing science interest using ANCOVA methods. Our questions for this paper and associated analyses are:

1. How did background characteristics relate to students likelihood of participating in the school fair? Advancing to the regional fair? (Logistic regression predicting group)
2. Controlling for pre-fair differences, did students who participated in a school fair show increased science interest, value, or self-efficacy? (ANCOVA)
3. Did the effects on interest, value, and self-efficacy differ for students whose projects did and did not advance to the regional fair? (t-tests)
4. What kinds of *transformative experiences* [11] did students who completed projects report? (t-tests)

The STEM-IQ Program

This data was collected as part of a project called "STEM-IQ: Science Technology Engineering and Mathematics Inquiry for Enhancing Science Education in Southeastern Alabama" that focused on introducing S&E fairs to high-needs and low-achieving schools as a means for improving science interest and achievement. The program's focus was schools located in the Alabama Black Belt, an agricultural region that is historically poor and has a large African American population. The districts this program served were primarily those that were under-resourced and with high levels of Free or Reduced Lunch (FRL) eligibility).

The program was designed around three cohorts of about 20 teachers. Each cohort began in successive years for three years of professional development. Cohorts were recruited in "vertical teams", which included two to three middle school teachers, two to three high school teachers, and one administrator from the same school district. This arrangement was intended to promote within-school and cross-school support system for student mentoring and S&E fair development. Multiple vertical teams from different school districts were included in each cohort.

The program was designed and implemented by a project team consisting of four science and engineering faculty members as well as staff from the College of Science and Mathematics (COSAM) Outreach office. All of the faculty and staff had extensive experience running the regional S&E fair program. Most of the faculty served as head judges each year at this event. A faculty member (first author) from the College of Education served as external evaluator for the program. Outreach staff and graduate students, in collaboration with the four science and engineering faculty, provided the professional development (PD) experiences and resources.

Over the course of the grant, for each new cohort, the project team continuously refined the training and support provided. The final iteration of the program, as provided to cohort 2 and 3, consisted of a week-long summer workshop for all of the teachers in the cohort. At this workshop, teachers received over 30 hours of professional development related to organizing an

S&E fair as well as in implementing inquiry methods to support high quality S&E projects that follow authentic science and engineering practices. Some years, this training involved implementing their own small-scale project and other years focused more on evaluating examples of student products from past fairs. In year two of their participation, each cohort returned for a 3-4 day workshop that provided additional training on needed or requested topics. In response to teacher requests, training topics expanded to address technical skills including statistical analyses, conducting social science research, differentiating engineering from science projects, and sterile lab techniques using basic equipment.

For each cohort, during the school year, one-day workshops on organizing the fair were organized. Teachers were also invited to attend the regional S&E fair. They also had the opportunity to travel to the international S&E fair to see the quality of projects that advance beyond the state fair. This latter opportunity required applying to participate and was limited in number. During the school year, the faculty and staff also were available for more informal interactions with teachers and students. Faculty were available as mentors to teachers and directly to students completing S&E fair projects, when requested, although this was uncommon.

One limitation to generalizability should be noted. The program strongly encouraged teachers either to require a project for all students or to strongly encourage girls and minority students to participate. As a result of the program's emphasis, the proportion of students from underrepresented groups are likely higher in this sample than if the teachers had no encouragement to seek diverse student participation.

Methods

Teachers administered a pre- and post-fair survey of science/engineering and fair-related attitudes to students in their science classes that included both students who did and did not complete S&E projects. Across two years, 32 teachers from two cohorts provided post-fair survey data from participating and non-participating students. We received data from 1,257 students at the beginning of the year, but just 982 at the end of the year. Our matching efforts identified 795 complete cases, which is the data we focus on here. See Table 1 for a breakdown of demographic information by teacher.

Measures

The evaluation team developed these surveys to assess student attitudes towards science and engineering as well as experiences being involved in S&E fairs. Measures of science attitudes (value and self-efficacy for science) as well as science and engineering interest were drawn from the MSP-MAP project[12] that developed theoretically grounded measures of constructs likely to be impacted by grades 6-12 science interventions. See Table 2. We also asked questions about whether students found S&E fair projects to be "transformative experiences"[11] which are expected to reflect deeper engagement with science. We shortened the scales for time, selecting the four most representative items from each scale. We also rephrased each question to ask about the fair project.

Results

We analyzed the demographic characteristics reported by these students and contrasted those who did and did not complete science fair projects. Overall, teachers with younger students (especially 6th grade) seemed more likely to require all students to complete a project, while teachers with older students (especially 12th grade) made the projects optional.

Table 1. Student demographic information by teacher

Teacher	Total	Grades	Fair Status: No project	Fair Status: Project, did not advance	Fair Status: Project, advanced	Race/Ethnicity [a]: African American	Race/Ethnicity [a]: Hispanic	Race/Ethnicity [a]: Asian	Race/Ethnicity [a]: White	Race/Ethnicity [a]: Mixed	Sex [a]: Female	Sex [a]: Male
1	12	7,8	10	2	0	8%		8%		83%		92%
2	32	7	1	27	4	6%		41%	9%	25%	47%	50%
3	73	6	4	42	5	4%	3%	34%	7%	37%	37%	34%
4	40	11,12	4	29	1	3%	5%	58%	5%		50%	35%
5	69	9	3	60	6			25%	7%	43%	62%	38%
6	61	9	7	41	11	5%		43%	2%	18%	52%	46%
7	38	10-12	30	3	2	5%		76%	8%		29%	50%
8	58	8	7	30	1		5%	14%	3%		53%	48%
9	35	9	12	18	0	3%		31%	3%		51%	43%
10	48	10-12	25	5	0	2%		2%	4%		65%	23%
11	35	8	0	30	5	11%		29%	6%	37%	63%	37%
12	20	8	20	0	0					100%	55%	45%
13	34	9	0	28	6					100%	47%	47%
14	36	5	37	0	0	6%	8%	64%				
15	38	11	34	1	0			84%	3%		55%	47%
16	62	12	33	26	8	6%		32%	6%		69%	39%
17	17	6	0	25	4			65%	12%			
18	30	8-10	29	1	0	3%	17%	43%	13%			
19	34	10-12	19	13	2	3%	3%	29%		38%	53%	47%
20	34	7	0	34	0	3%		29%		53%	56%	44%
21	69	6	0	47	18	16%	3%	42%	6%	17%	57%	38%
22	57	7	8	18	7	7%		51%	2%		44%	25%
23	34	8	0	29	5	12%		68%	3%	3%		
24	37	7	13	22	1	3%		49%	19%		57%	41%
25	40	6	0	34	0	3%		33%	10%		55%	30%
26	68	11	19	37	7	6%		26%	7%	25%	54%	43%
27	40	6	0	28	4	3%	3%	65%	13%		55%	45%
28	35	8	0	27	8		3%	54%	6%	29%	51%	49%
29	29	8	2	21	6			66%	7%	21%	69%	31%
30	40	9	29	6	0	10%		68%	8%		48%	48%
31	35	9	16	15	2	11%		17%	3%		57%	34%
32	75	8	37	33	5	1%	3%	40%	7%	39%	52%	48%

Note. [a] Numbers may not add up to 100% due to missing data.

Table 2. Scales and internal consistency estimates

Scale	**Cronbach's α (Pre/Post)**	**Items**
Self-efficacy for Science (n=5)	.72/.85	I am good at science. I believe I will receive a good grade in science class. I am confident I can understand the basic concepts taught in my science class. Even if the work in science class is hard, I can learn it. No matter how hard I try, there are some science topics I'll never understand.*
Interest in Science and Engineering (n =11)	.86/.77	I like science. I would like to work in science someday. If I had a choice, I would not study any more sciences.* A job as a scientist would be boring.* I would like to work in engineering someday. Science is a subject that I like to study in school. I would like to study science in college. I would like to study engineering in college. I think that what we are learning in my science class is interesting. I would like to be a science teacher someday. A job as an engineer would be exciting.
Utility/Value of science (n =6)	.87/.87	Science is useful for me to learn. Science is useful for solving everyday problems. I can use what I lean in science to do other things besides schoolwork. When I grow up, I will need to know how to do science. It is important for me to learn the course material in my science class. I believe that knowing science will help me get a job someday.
Transformative Experience: Motivated Use (n=4)	--/.81	Outside of school, I talk with others about concepts from my science and engineering fair project. I apply the knowledge that I've learned from my fair project during class. I apply the stuff I've learned from my fair project even when I didn't have to. I look for chances to apply knowledge from my fair project in my everyday life.
Transformative Experience: Expanded Perception (n=4)	--/.84	I think about science or engineering differently given what I have learned from my fair project. The concepts I learned from my fair project changed the way I see the world. I notice examples of science or engineering concepts in my everyday life that I would not have noticed before doing my project. Concepts I learned from my fair project help me to better understand the world around me.
Transformative Experience: Experiential Value (n=4)	--/.84	Knowledge of concepts from my fair project is useful in my everyday life. What I learned from my fair project makes the world more interesting. In class, I find it interesting to learn about concepts related to my fair project. Outside of school, I find it exciting to think about concepts from my fair project.

Note. Transformative Experience scales administered at post-test only. * Reverse scored.

We used logistic regression to determine if other demographic variables predicted participation or advancing to the regional fair. These demographic variables included sex, parent education level (divided into "high school degree or less" compared to "college or advanced degrees"), current academic performance ("worse than most other students", "about the same", or "better than some other students"), and race/ethnicity (Hispanic, African American, Asian, Multi-racial, white).

Table 3. Logistic regression results for completing a project [1]

	Predicting whether student completed a project					
	B	S.E.	Wald	df	Sig.	Exp(B)
Sex	-0.087	0.200	0.188	1	0.665	0.917
Race/ethnicity						
African American	-0.162	0.203	0.640	1	0.424	0.850
Hispanic	-0.092	0.420	0.048	1	0.827	0.912
Parent or guardian education						
Father college degree	0.020	0.217	0.008	1	0.928	1.020
Mother college degree	0.156	0.225	0.482	1	0.488	1.169
Current performance:						
Better than most	0.039	0.209	0.034	1	0.853	1.040
Don't know or worse	-0.016	0.334	0.002	1	0.961	0.984
Grade level	-0.435	0.055	63.612	1	<0.001	**0.647**
Constant	4.767	0.571	69.652	1	<0.001	117.583

Note. Sex reference group was male. Race/ethnicity reference group was white. Parent education reference group was "high school degree or less". Performance reference group was "About the same". Smaller race/ethnicity groups were suppressed because they lacked statistical power.

When looking at which students advance from the school fair to the regional fair, demographics variables had more pronounced effects (Table 4). Girls were 90% more likely than boys to advance from the school to regional fair. African American students were 80% less likely than

[1] We used two logistic regressions rather than a multinomial model because for this variable we wanted to see if demographic variables predicted completing a project, regardless of whether it advanced.

White students to advance. Finally, students whose mother had at least a college degree were 110% more likely than other students to advance.

Table 4. Logistic regression results for advancing to the regional fair

	Predicting whether project advanced to regional fair					
	B	S.E.	Wald	df	Sig.	Exp(B)
Sex	0.645	0.289	4.993	1	0.025	**1.907**
Race/ethnicity						
African American	-1.459	0.372	15.371	1	<0.001	**0.233**
Hispanic	0.328	0.480	0.466	1	0.495	1.388
Parent or guardian education						
Father college degree	-0.119	0.315	0.143	1	0.705	0.888
Mother college degree	0.755	0.355	4.537	1	0.033	**2.128**
Current performance:						
Better than most	0.355	0.293	1.471	1	0.225	1.426
Don't know or worse	-0.126	0.507	0.062	1	0.803	0.881
Grade	0.053	0.074	0.507	1	0.477	1.054
Constant	-2.645	0.739	12.813	1	<0.001	0.071

Note. Sex reference group was male. Race/ethnicity reference group was white. Parent education reference group was “high school degree or less”. Performance reference group was “About the same”. Smaller race/ethnicity groups were suppressed because they lacked statistical power.

It seems unlikely that all of these demographic differences are due to judging bias. What is much more likely is that these variables are confounded with access to greater resources or parental support. We asked students a few questions about their project experience. Very few (less than 10) reported working with a university lab on their project, so this was not likely a factor. Across the significant variables (races, mother education, and gender), there were no differences in whether the students worked in a group or alone. When asked where they got the materials for their project, white students were more likely than Black or Hispanic students to list local businesses or universities as one source of materials (10% vs. 5% for other groups; Chi-square $p < .10$). Comparing girls and boys, girls were less likely than boys to list local businesses or universities as a source (7% vs. 11%, Chi-square $p < .05$) and more likely to list their school than their family as the source of materials when only one was listed. Having family support (including buying materials) and the support of local businesses may be an influence on success either because the student was more motivated/pro-active, the parents were more motivated/pro-active, or because the topic itself was complex and advanced enough to warrant more support. Further research is needed on how access to resources influenced success and is differentially distributed among students by race or gender.

Impact of Fair Controlling for Pre-Fair Differences

We compared the three groups of students in terms of their science interest, self-efficacy, and value perceptions: those who did not complete a project, those who completed a project but did not advance to the regional fair, and those who did advance to the regional fair. For those students not completing a project, efficacy and value actually decreased moderately during the school year. This is consistent with work showing that science attitudes tend to decline in junior high and high school. Students who completed a project that did not advance showed stable attitudes over the school year (which may actually be an improvement if overall they would decline!) Finally, students whose projects advanced showed substantial increases in all of the attitudes. This is especially impressive as none of these attitudes showed differences between groups at the pre-survey.

We ran ANCOVA analyses looking at the effect of participation in the S&E fair, controlling for pre-fair attitudes. Differences were found in all attitudes between students completing no projects, projects, and projects that advance. The only group difference that was not significant was the difference between students with no project and projects for science values. Students completing projects that advance always had the highest means. This confirms the results of the direct analyses in Table 5.

Table 5. Comparison of students' science attitudes before and after the fair (all students)

		Pre-fair		Post-fair					
Group of students		M	SD	M	SD	t	df	Sig. (2-tailed)	Cohen's d
No project	Interest	2.92	0.66	2.85	0.63	1.37	242	0.17	-0.11
N=243	Efficacy	3.79	0.85	3.51	0.93	3.96	242	0.00	**-0.31**
	Value	3.58	0.82	3.38	0.87	2.97	242	0.00	**-0.23**
Completed Project, did not advance	Interest	2.84	0.67	2.90	0.68	-1.68	463	0.09	0.09
	Efficacy	3.64	0.91	3.62	0.92	0.26	463	0.79	-0.01
N=464	Value	3.66	0.83	3.66	0.83	0.19	463	0.85	-0.01
Completed Project, advanced	Interest	3.00	0.67	3.21	0.65	-3.02	81	0.00	**0.32**
	Efficacy	3.84	0.97	4.13	0.81	-2.54	81	0.01	**0.32**
N=82	Value	3.75	0.89	4.18	0.59	-3.82	81	0.00	**0.56**

Note. Significant effects in bold.

Impact of Advancing to Regional Fair

We were able to compare the transformative experience value of projects between students whose projects advanced to the regional S&E fair and those who did not. The transformative experiences scale [11] was designed around three types of experiences: motivated use (including looking for opportunities to learn more), expanded perception (noticing connections of the topic to everyday life), and experiential value (a sense that they have learned something useful). Only students who completed a project completed this survey.

Prior to the fair, we found no significant differences in the interest, efficacy, or value of these students. However, after the fairs, we found that students who advanced had greater interest, efficacy, value, and two of the three types of transformative experiences (Table 6). Although we cannot be certain whether it was the experience of being successful in their project or the topic itself (or being the kind of student who completes a high quality project), this is certainly an encouraging finding for the value of science fairs.

Table 6. Comparison of students who did and did not advance to regional (all completed projects)

	Did not Advance (N=730)[a]		Advanced to regional (N=118)					
Attitudes	M	SD	M	SD	t	df	Sig. (2-tailed)	Cohen's d
Science & Engineering Interest	2.91	0.70	3.21	0.70	-4.25	846	<0.001	**0.42**
Science Self-Efficacy	3.67	0.81	4.09	0.66	-5.34	846	<0.001	**0.57**
Science Utility Value	3.62	0.90	4.09	0.84	-5.24	846	<0.001	**0.53**
Project interest	3.09	1.09	3.98	0.99	-8.212	833	<0.001	**0.85**
Transformative experience								
Motivated Use	2.65	1.12	3.41	1.15	-6.782	833	<0.001	**0.67**
Expanded Perception	2.33	1.05	2.91	1.15	-5.402	832	<0.001	**0.52**
Experiential Value	2.49	1.09	3.03	1.10	-4.931	832	<0.001	**0.49**

Note. [a] Sample size much larger because no data was lost to matching.

For all students completing a project, the highest ratings were for motivated use (M=2.75, SD=1.16; scale 1-5). The lowest average ratings were for expanded perception (M=2.41, SD = 1.08). This suggests that completed science fair projects led to experiences that students liked to talk and learn more about their topic. They also saw the experience as somewhat valuable to them (M=2.57, SD=1.10).

Comparing these groups for transformative experience (Table 5), we found students who went on to the state fair were more likely to report having all three types of transformative experiences. We expected that students who had projects that advanced were more likely to report motivated use of the topic of their project. This was the largest effect.

Discussion

Our first research question addressed whether, when projects were generally optional, students from different gender or racial/ethnic background were equally likely to complete a project. We hoped to find no differences, reflecting that in our project schools, all students were having similar opportunities to engage in science and engineering projects. We found no differences, which suggests there was equity in participating in the fairs. Unfortunately, significant differences in advancing to the regional fair were found for gender, race, and mother's education, suggesting a possible route for future research into qualitative differences in the projects that these students complete and/or judging disparities at the school fairs. It should be noted that local fairs often struggled to recruit judges and training was minimal.

Quasi-experimental methods allowed us to explore the impact of completing S&E fairs on student gains on science self-efficacy, interest, and value perceptions. Controlling for pre-existing differences in these attitudes, we found that students not completing projects actually showed declines in their science attitudes during the year. Students who completed projects maintained similar attitudes, while those whose projects advanced had substantial gains on all three variables. It is unknown whether this gain can be attributed to the experience of engaging with a quality project, from being the kind of student who completes a quality project, or some other factor.

We also explored whether students reported that their projects provided a "transformative experience" that includes deeper engagement with science and perceiving connections to the student's academic and everyday life. The strongest area of transformation students reported overall was in Motivated Use, which reflects students connecting their project to learning in the classroom or to their extracurricular interests. Comparing students who presented projects only for the school fair to those who advanced, we found that students who advanced had all types of transformative experiences, meaning they were engaged in thinking about their project, found connections in their everyday life, and found their topic valuable.

Conclusion

The theory of action for this program was that encouraging all students to complete S&E fair projects and supporting the quality of projects would lead to an expansion of the number and diversity of students who are engaged and excited about science and engineering. Indeed, our findings suggest that students who complete projects and advance to the regional fair had the most positive outcomes in terms of attitude and transformative experiences. The overall strong representation of girls, African American, and Hispanic students suggests that overall the program had its intended effects in increasing the positive impact that S&E fairs have on all students in our region.

An interesting path for future research is to better understand why students whose projects advanced to the regional fair had better outcomes than those who only presented in the school fair. Did they land on a topic that sparked interest? Did they have the support of family or teachers to complete better projects? To some extent, our methods allow us to rule out differences in motivation or interest as causes of completing better quality projects (and thus advancing to regional). Future research could explore the obstacles that students encounter in selecting projects that align with their interests *and* lead to successful projects (by fair standards). Such projects seem most likely to spark sustained interest in science and engineering for more students.

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