Board 384: South Dakota Mines Art + Engineering Engagement in Co-Curricular and Community-Focused Events

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Dr. Katrina Donovan received her B.S. degree from South Dakota School of Mines and Technology in 2010. She received her Ph.D. in Materials Science from Oregon State University in 2019, studying microfluidic investigations of capillary flow and surface phenomena in porous polymeric media for 3D printing. She worked for multiple years at HP, Inc. in the 3D Printing Department. She is currently a Lecturer at South Dakota Mines and Research Scientist at Dragon Materials, LLC, an engineering consulting firm. Her research involves experimental design and technique development for soft materials, complex fluids, and surface phenomena. She a wide range of experience in rheological, thermal, structural, and molecular characterization that she leverage fundamentally for academic purposes as well as industrially for applications. As her three patents can show, designing experiments and creating novel techniques to answer fundamental questions that drive applications and technology forward captivates her interest. She has volunteered countless hours to the community, led multiple STEM Education grants that engage the local K-12 schools of the Pine Ridge Indian Reservation, and submitted proposals that engage even more tribal communities.

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Program Background

The Art + Engineering (A+E) program at South Dakota Mines, funded by the National Science Foundation (NSF) through the Improving Undergraduate STEM Education (IUSE) grant number #2120156, has been integrated into all levels of the undergraduate Metallurgical Engineering curriculum. The professional field of Metallurgical Engineering traditionally lacks diversity, and the Metallurgical Engineering program at South Dakota Mines faces the additional challenge of being in a rural area at a university that typically does not attract a diverse student population. Thus, the A+E programmatic elements focus on creativity and critical thinking components, with the goal of attracting and retaining a more diverse student population.

The research hypothesis for this program is that "*Positive outcomes can be achieved in an engineering program through strategic curricular and co-curricular modifications that integrate and embrace STEAM program development. Outcomes targeted include innovation, creativity, collegiality, entrepreneurship and broadening of the STEM talent pool [1].*"

The team has made significant progress in the first and second years of the program [2-3]. The A+E team has advanced into the third phase (approximately halfway through the three-year award) of the NSF IUSE grant. Notably, the program has reinvigorated the curriculum, including the formation of two new courses and creation of a new Minor. Additional curricular advances have been made and can be found in prior literature [2-3]. This paper focuses on A+E outreach at multiple levels: community (post-high school), K-12 teachers, K-12 students, and campus (see Figure 1).

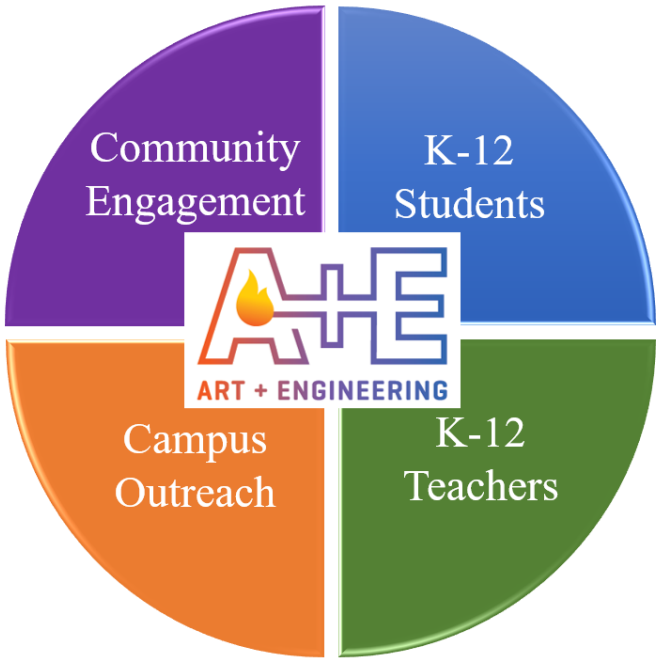

Figure 1: A+E approach to STEM outreach.

Community Engagement

A wide variety of A+E events have been offered to the community, examples include Women-In-Science Days [4,5] to Fine Arts in the Hills [6]. The three major A+E highlights discussed here are an A+E Mixer, the one-day A+E Workshop for teachers and community members, and execution of a Memorandum of Understanding (MOU) between South Dakota Mines and the Rapid City Arts Council.

The A+E Mixer was a networking event hosted at Elevate Rapid City on September 15th, 2022. The mission of Elevate Rapid City is to promote economic development for Rapid City and the Black Hills region. The mixer created an opportunity to inform stakeholders what the A+E program has accomplished, solicit input on programmatic elements going forward and to discuss potential collaborative opportunities. The mixer was also a celebration and a chance for interested parties to network in Elevate's new facility. The keynote speaker of the evening was artist and Professor Quintin Owens, a well-known local artist and academic (Black Hills State University) who integrates Computer Aided Design, Clay 3D printing, and art in his courses. Owens' keynote, titled *Science + Art + Technology*, focused on the intersection of these disciplines and the creative opportunities for collaboration.

The feedback from the networking conversations was extremely constructive and collaborative, with multiple attendees expressing interest in learning about art from a scientific perspective. This sentiment was supported by a survey from the event, with 100% of respondents endorsing a day-long (no cost) A+E workshop focusing on the integration of arts (local artists) and science/engineering (South Dakota Mines faculty). This feedback prompted the A+E team to plan and offer the summer A+E Workshop which has now become an annual workshop at South Dakota Mines. Another key insight from this event, supported by both conversations and the survey was that various organizations (e.g., Rapid City Arts Council, Racing Magpie, Newman Center, Journey Museum) were interested in collaborating with the A+E program.

The A+E Workshop, as mentioned above, is a one-day workshop offered to the community. High school teachers and artisans interested in understanding more about the science and engineering of ceramics, glass, and metals were invited to attend. The workshop features science-based lectures and hands-on glassblowing, stained glass, ceramic, and blacksmithing activities. The ten participants of the initial workshop were all women with diverse backgrounds (e.g., artists in the community, high school art and STEM education teachers, Director of Education for the Rapid City Arts Council). Figures 2A and 2B feature images of community members who participated in the workshop.

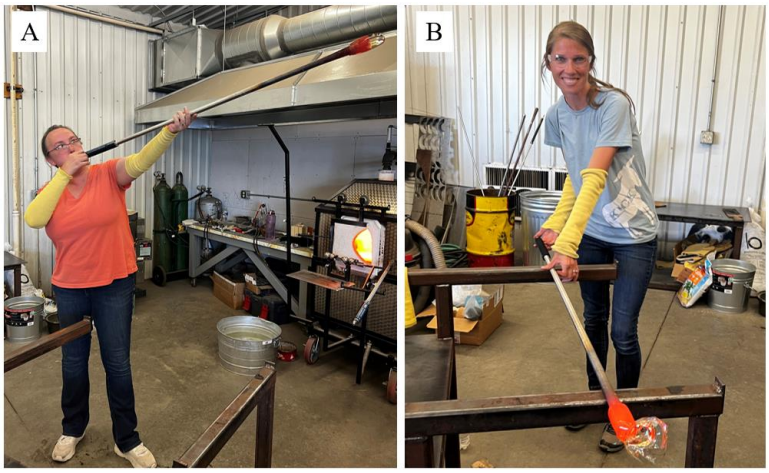

Figure 2: (A) Artist and community member, Christy Robinson in the process of blowing a glass bubble. (B) High school art teacher Alicia English displaying her glass bubble.

A survey for the A+E workshop was conducted with a key focus to ask the respondents the following question.

Q1. Did the A+E event increase your understanding of the science behind the training activity?

This question has become a foundational question for the A+E outreach activities to self-assess our interactions with attendees. For the A+E one day workshop all of the respondents selected that their scientific knowledge was increased by the event.

We recognize that the impact the A+E program attendees can have in their schools and communities is substantial. For example, networking from the A+E Elevate Mixer, and the attendance of the Education Director for the Rapid City Arts Council Staff at the one-day A+E Workshop laid the foundation for a Memorandum of Understanding (MOU) between South Dakota Mines and the Rapid City Arts Council. The MOU will facilitate future collaboration and support between the two organizations.

K-12 Student Engagement

The A+E team engaged with the local K-12 student community in numerous outreach activities. One event hosted over 800 young women in 7th and 8th grade on South Dakota Mines's campus for the annual Women in Science event [4,5]. Another annual event that the A+E team has participated in the past three years has been the Girl Scouts at the *Believe in Girls (BIG)* event which has hosted almost 200 young women (K-12) [7]. While these events are impactful opportunities and provide the opportunity to interact with a large body of students, they also do not provide the same value as small groups activities or small group mentoring does. Thus, this section focuses on two programs, the A+E Summer Camp and the Army Internship Program, that provided high school students the opportunity to have impactful peer and faculty mentoring experiences.

The first program was the 2nd annual A+E summer camp titled, "*The Science of Pottery and Glass*". The second year of the program allowed for faculty to refine the previous year's curriculum and create the opportunity for students to explore the science of glassblowing. The students were exposed to STEM content that included, but was not limited to, color theory, clay-body formation, clay body processing, glass and glaze creation, and characterization. Figures 3A-C are examples of the activities and products that the students created.

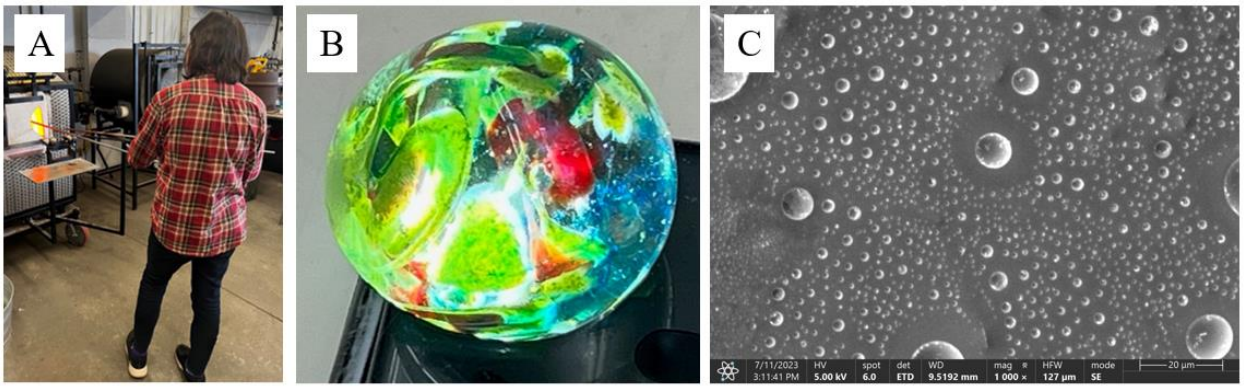

Figure 3: (A) Local high school student preparing to gather molten glass to create a (B) glass paperweight. (C) Scanning electron microscopy was utilized to analyze the porosity of a ceramic glaze coated surface at 1000x magnification.

The program engaged a diverse group composed of ~30% indigenous students and ~86% female students. A survey was provided to the seven students, five of the students completed the survey which was a combination of self-assessment and opinion questions. Q1(*Did the A+E event increase your understanding of the science behind the training activity?)* was to these students. All five of the students responded that their scientific understanding was "*very much*" enhanced by the A+E Summer Camp.

The second program was the *Army Educational Outreach Program (AEOP) Apprenticeships and Fellowships program*. The AEOP program *"brings real world STEM experiences to students seeking to enhance their knowledge in science, technology, engineering and math that complements the things they're most passionate about."* [8,9] The program supported two regional students to be engaged in immersive (200 hour) individual research projects that were part of a larger effort. The first student worked on slip casting local minerals into ceramic bodies also known as pottery. The second student formulated and optimized ceramic coatings (glazes). The students and their research were featured on news feeds of Rochester Institute of Technology's and South Dakota Mines' media pages. [7,8]

K-12 Teacher Engagement

The A+E team engaged directly with the local teachers in two specific areas. The first was the summer A+E Workshop which was previously discussed in community engagement section. In addition to the teacher's professional development, the A+E Workshop also provided the teachers the opportunity to earn continuing education contact hours and return with content to incorporate into the classroom. The second major event of note is the annual South Dakota STEM Education

Conference where the A+E team offered hands on programming for the past three years. At this conference the team hosts multiple professional development seminars focused on metal clay and ceramic science and engineering. The annual South Dakota STEM Education conference boasts over 300 teachers from across multiple states to listen to presentations and experience kinesthetic hands-on learning.[10] In spring of 2023, the presentation delivered by the A+E team was featured on the front page of the local paper. [11] A large portion of the A+E recruiting for the high school student camp and A+E workshop occurred at the South Dakota STEM Education conference.

Campus Outreach Engagement

The A+E team has made a concerted effort to engage the community, especially the local teachers and students. The A+E team have focused on strategic campus outreach opportunities for the students in a tri-fold effort to *(i)* engage with other departments on campus, *(ii)* spread the word about the A+E space on campus (including campus admissions staff), and *(iii)* improve campus culture for students, faculty, and staff. Numerous campus engagement opportunities have occurred, but this section will be limited to one specific event which include an A+E Day for campus Mechanical Engineering (ME) students.

New A+E infrastructure has been critical for outreach activities. Specifically, the creation of the glassblowing studio [12] and the expansion of the A+E pottery studio have allowed for larger scale outreach events. One such event was the first annual A+E Day for mechanical engineering (ME) students hosted for the first time in the fall of 2023 for the ME 110: Introduction to Mechanical Engineering class. The event was such a success that there are plans for a second A+E Day for ME in the spring of 2024 semester. The "day" consisted of a three-hour lab block split into two 90-minute sections that hosted 65 students across five modules – glassblowing, welding, blacksmithing (forging), casting, and glazing. The overarching theme of the kinesthetic modules was thermodynamics in materials processing, and the students all received a lecture on the subject prior to attending lab. The verbal feedback from the students was positive, the ME students were also asked to complete a survey. The students were surveyed, and the results from three questions from the survey (see questions below) are shown in Figure 4.

Q1. Did the A+E event increase your understanding of the science behind the training activity?

Q2. Did the A+E event improve your overall mood?

Q3. I believe A&E components would help students develop more creative engineering solutions.

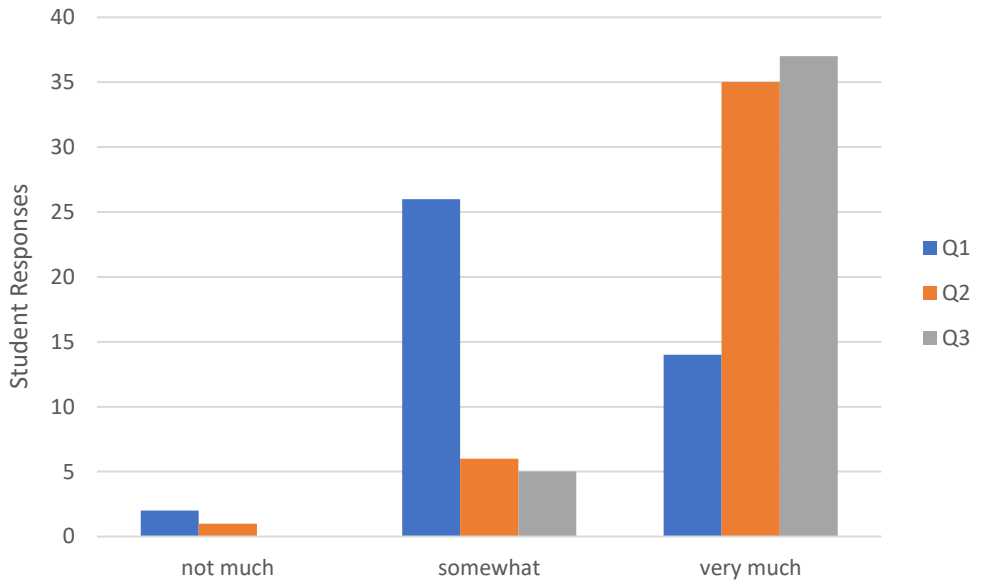

Figure 4: Results of the survey provided to students participating in the ME 110 A+E Days (n=42).

The first question (Q1) addresses scientific merit behind the activity. A large majority (~62%) of the student assessed the training as "somewhat" improving their scientific understanding, the result is not completely surprising as a singular lecture on thermodynamics attempted to cover five separate processes with multiple materials (ceramic, glass, and polymers) and phases (solid, liquid, and glass). In the future, individual, focused thermodynamic lectures will be offered. Additionally, the survey did not assess if there was one module more so than another that emphasized the science behind the module.

At face value Q2 appears to be a non-technical question, however retention in science and engineering disciplines can be a challenge [13]. The retention challenges can be due to a number of things *(i)* interest in subject matter, *(ii)* rigor and challenge of the curriculum, and *(iii)* limited opportunities for creative outlets on a campus and/or within the curriculum [14,16]. The survey indicates that ~83% of the respondents left the training with their mood "very much" improved and only one individual (~2%) reported that there was "not much" improvement in mood. The A+E team believes this finding warrants further exploration, as improved mental well-being could be a very positive and unanticipated outcome from the A+E program.

Q3 begins to probe and potentially answer the research hypothesis in regard to creativity being an outcome of the A+E program. Of the respondents, 88% of the students stated that these modules would "very much" help develop more creative engineering solutions. No student respondent selected "not much", suggesting that all respondents experienced the creative value the modules delivered.

Overall, the A+E Day for ME students was a deemed a success by the A+E team and will occur for the second semester (Spring 2024).

A+E Outreach Overall Assessment

Over the past nine months, the A+E team has made a concerted effort to survey and assess the various outreach activities that have been implemented. Table 1 below summarizes a variety of the outreach activities assessed (by survey), there are 91 respondents.

Table 1: Compilation of A+E Outreach activities and the corresponding number of responses.

A+E Outreach	Number of Respondents
REU Student Team Building	4
A+E Staff Appreciation	23
A+E Open Pottery	11
A+E Admissions	6
A+E ME Day	42
A+E Summer Camp	5

Not every A+E outreach shown in Table 1 was discussed in the previous sections. For example, the A+E Staff Appreciation Days and a scientific glass blowing team building module for an NSF REU Site students were not covered herein. Additionally, outreach that was discussed has not yet been assessed (e.g., 7th and 8th Grade Women in Science Days).

Figure 5 provides a plot of the responses for Q1 (*Did the A+E event increase your understanding of the science behind the training activity?*) across all A+E outreach events listed in Table 1. The blue bars in Figure 5 represent the collective response, and an overall strong response of "somewhat" and "very much" were selected by all respondents. This result suggests a transfer of scientific knowledge is occurring at the A+E Outreach events. Of the 91 responses, 42 of those responses were ME students from the A+E ME Day event. While, the team assessed these activities, two important items to note is that (1) the ME Day was more co-curricular than outreach, and (2) the ME students account for ~46% of the responses.

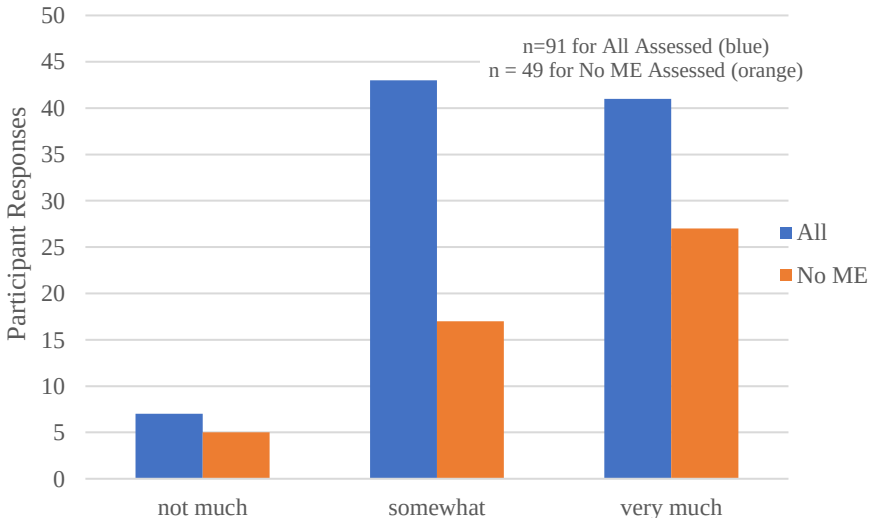

Figure 5: Survey responses from A+E outreach event attendees.

The orange bars in Figure 5 represent the respondents' views on activities that are more outreach focused rather than co-curricular, specifically the responses from ME students were excluded from the assessment. The survey reveals an upward trend in respondents increased STEM acumen. Specifically, more than ~90% respondents selected "very much" and "somewhat", while only five individuals (~10%) stated that there was not much increase in their scientific knowledge.

The individual survey responses to all the questions were reviewed and analyzed for the individuals that selected "not much" for Question 1 as illustrated in Figure 5. These responses revealed that although they may have not felt that they learned much scientifically (Q1) they ALL reported that their overall mood improved (Q2). Upon reviewing the overall results (all 91 responses) of Q2, the survey reveals that 98.9% of respondents reported a positive mood after completing the module.

Conclusion

The A+E outreach program has been successful across several focus areas (Figure 1). However, improvements in the delivery of scientific content should be considered to enhance the overall outreach effectiveness. Notably, the positive changes in mood consistently reported throughout these activities are very important for recruitment and retention purposes and warrant further investigation.

The A+E team will focus on continually improving and expanding the learning and outreach modules. For example, the A+E team is developing step-by-step modular instructions for the Metal Clay tutorial the teachers experience at the South Dakota STEM Education conference that could be modified to use the teachers' current resources (which can be limited in a K-12 setting). New and expanded A+E programming is planned for the numerous teacher workshops, high school summer camps, high school research programs, and undergraduate research programs for the third year of the program.

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