BOARD # 276: NSF IUSE: Art + Engineering: Translating Local Mineral Research to a High School Classroom

Dr. Katrina Donovan, South Dakota School of Mines and Technology

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 the 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 involve 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 has submitted proposals that engage even more tribal communities.

Dr. Jon J Kellar, South Dakota School of Mines and Technology

Kellar is the Douglas Fuerstenau Professor of Materials and Metallurgical Engineering at the SD School of Mines and Technology. He has been on the faculty since 1990, and in 1994 was selected as an National Science Foundation Presidential Faculty Fellow a

Technical Education Program

A ceramic STEM module for high school chemistry courses was developed. The curriculum was mapped to the learning objectives established by the SD Education Association [2]. Table 1 demonstrates the alignment between ceramics (e.g., clay, glaze, and glass) content and the course learning objectives. Through our prior educational outreach delivery (e.g., STEM Ed conference, teacher workshops, high school camps, artisan workshops), we have developed culturally relevant, and regionally focused, curriculum for our student populations [3][4][5].

Table 1. Potential Course Learning Objectives—based upon SD Process Guide [2] *(example content)*.
9-12.N.1.1 Students will be able to evaluate a scientific discovery to determine and describe how societal, cultural, and personal beliefs influence scientific investigations and interpretations. *(the discovery of porcelain, its chemistry and its relevancy to clay-based ceramic fabrication)*
9-12.N.2.2 Students will be able to practice safe and effective laboratory techniques. *(safety training prior to lab sessions: glassblowing, potter's wheel, pug milling, stained glass, scanning electron microscope)*
9-12.P.1.1 Students will be able to use the Periodic Table to determine the atomic structure of elements, valence number, family relationships, and regions (metals, nonmetals, and metalloids). *(use concept of electronegativity to predict which elements would be expected to form ceramics)*
9-12.P.1.3 Students will be able to predict whether reactions will speed up or slow down as conditions change. *(use the role of particle size as it relates to the concept of sintering of ceramics)*
9-12.P.1.5 Students will be able to distinguish among chemical, physical, and nuclear changes. *(use the concepts dehydration and sintering of clay-based ceramics to understand change in dimensions and chemistry)*
9-12.S.1.2 Students will be able to evaluate and describe the impact of scientific discoveries on historical events and social, economic, and ethical issues. *(use materials evolution to understand advancement of civilization)*
9-12.S.2.2 Students will be able to analyze factors that could limit technological design. *(use glaze chemistry to understand color generation and aesthetics)*

Pilot High School Program, Summer-Fall 2024

Ms. Michelle Crane, co-author and high school teacher at Douglas High School, has performed scientific research (Summer 2024) on ceramic glaze formulations using 100% local materials from the Black Hills while being funded by the SD EPSCoR NASA Research Experience for Teachers. Crane has developed formulations of local minerals to produce a ceramic coating (glaze). The coating provides a non-porous surface that will improve the mechanical properties of the material. Figure 1 illustrates the coated vitreous (glass/glaze) coating and the porous clay body portion. The image is a cross-section of the local Belle Fourche Shale clay body (right side) with a glaze coating the surface (~59.7 microns thick) was taken using a Scanning Electron Microscope (SEM).

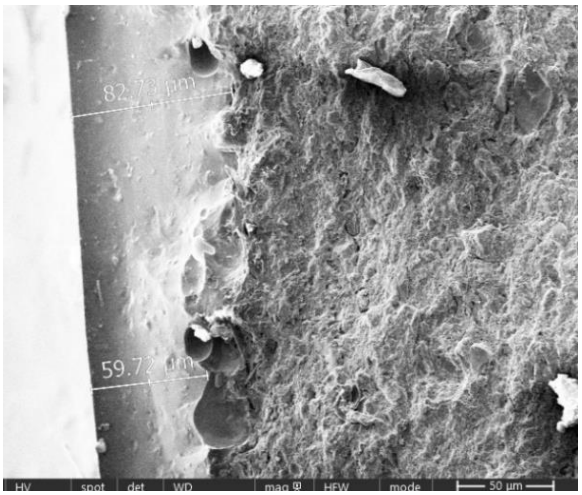

Figure 1: SEM image of glaze coating (thickness is ~59.7 microns) on left and porous clay body on right at 350x magnification.

The Summer 2024 research experienced helped inform the curricular development Fall 2024 (Chemistry class). Crane focused on ceramics – both clays and glazes. The Curriculum was focused on evidence-based learning. For the on-campus (South Dakota Mines) delivery, technical content focused on kinesthetic topics that include operating the potter's wheel, Near Infrared Spectroscopy (NIR) and the SEM (*addressing Table 1 Learning Outcomes 9-12.N.2.2).* Students experienced the challenges faced by constraining their material selection to the Black Hills (*9-12.S.2.2).* In addition to a field trip to South Dakota Mines, Crane also plans

to invite an industrial speaker into her class (*9-12.S.2.3; 9-12.S.1.2; and 9-12.N.1.1*) to discuss ceramic materials, applications, and career opportunities.

On campus Student Activities

While on the South Dakota Mines (SDM) campus, the students had the opportunity to engage with three faculty members (two STEM faculty and one Art faculty), two research scientists, and numerous undergraduate students. Table 2 outlines the student's schedule while on campus. The italicized names are the individuals that were leading that part module or activity.

Table 2. Schedule of activities and locations for the students throughout the day.

Time	Activity	Location
8-9 am	Welcome Intro- *Donovan*	Makerspace
9-10 am	Rotation 1	MI 220
10-11 am	Rotation 2	MI 220
11am-12 pm	Rotation 3	MI 220
12-1 pm	Lunch & Research Talk - *Nathan Madden*	Classroom Building 110
1-2 pm	Campus Tour - *Admissions*	Campus
2-3 pm	Back to Douglas - *Crane*	School Bus
Module Rotations		
Group 1: SEM/TEM (*Madden*)	**Group 2:** Arbegast Materials Processing & Joining Tour (*West/ Sjovall*)	**Group 3**: Ceramic Processing & NIR (*Whitehead/Crane*)

Throughout the morning the student's had the opportunity to engage in the all the rotating modules, see Figure 2. The students had a unique opportunity to work on a Scanning Electron Microscope (see Figure 2a), Near Infrared Spectroscopy (see Figure 2d), and a Transmission Electron Microscope (TEM). The students also had a guided tour through the Arbegast Material Processing & Joining facility (see Figure 2b).

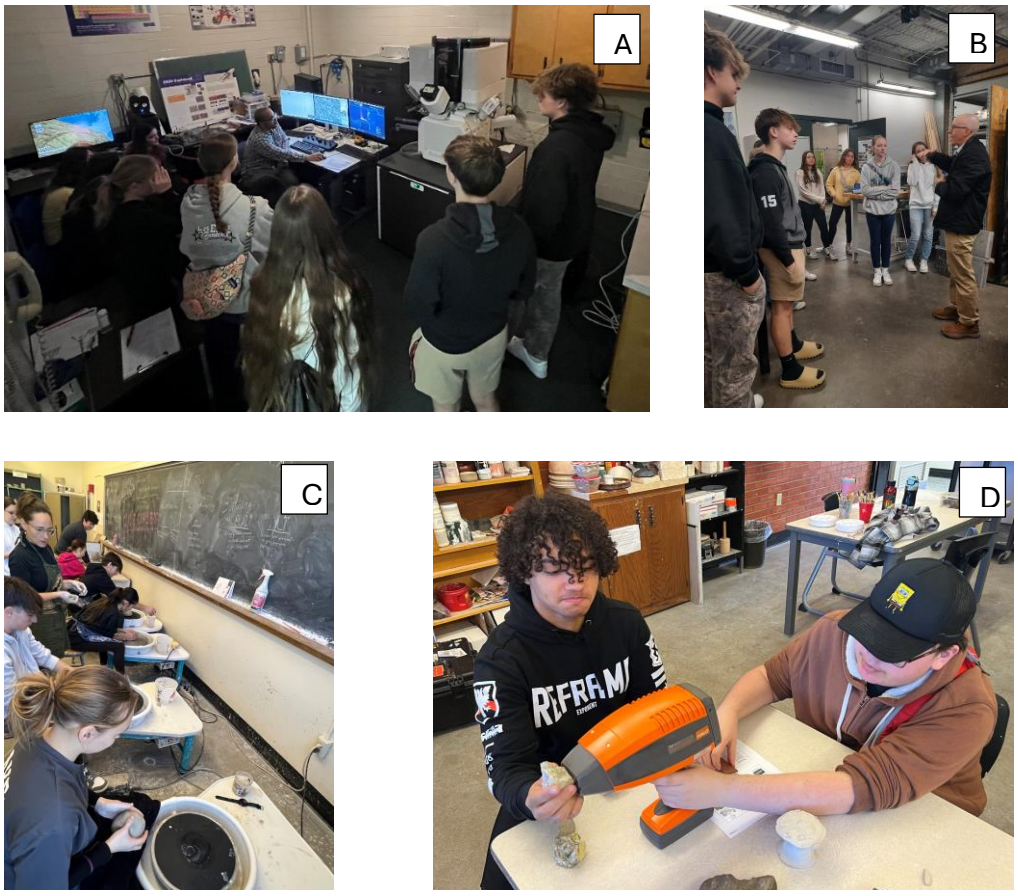

Figure 2: (a) Students viewing the microstructure of clay and glazes on a Scanning Electron Microscope, (b) students on a tour through the AMP facility, (c) students applying their knowledge of clay processing to wheel throwing , and (d) students using the hand-held infrared spectrometer to identify different rocks based on their crystal structure.

The students have had the opportunity to learn about the chemistry of the clay body and glazes in class prior to coming to SDM, but they hadn't had the opportunity to learn about mineral processing and clay forming. They were able to work on that stage of the process at SDM (see Figure 2c). The students also had the unique opportunities to have a guest speaker at lunch, Dr. Nathan Madden, an alumnus of Douglas High School, who spoke about his academic journey and current profession.

Assessment

The program objectives for the on-campus modules were trifold: *i)* supporting our local STEM teachers in a way that would assist the educators in meeting the course learning objectives was vital, *ii)* bringing students to a college campus creates several opportunities for them and lowers the activation barrier to consider college a viable option post high school, potentially even a career in the STEM field, and *iii)* designing a program to balance challenge technical content delivered in class with a fun kinesthetic approach to STEM to leave students with positive feeling about STEM topics and institutions.

A survey of the students was performed in the days following the event to assess how their opinions on the program and develop or improve the program. A reminder that this audience was NOT all students that were solely interested in STEM, but students that have a broad array of potential careers interests after high school.

Through the survey, there was a subtle shift in mindset. When asked if they had an increased interested in pursuing a STEM degree, there was a 1 student (n = 15) shift their response from *not much* to *somewhat.* Initially (or before the program), 60% of the students stated that they are *somewhat* or *very much* interested in pursuing a STEM degree. While this shift may not seem significant, there one important thing to note is that as a small specialty focused school (STEM degrees only) small, positive shifts are important to us, and even more so in niche fields like Metallurgical Engineering.

Three survey questions (below in italics) for the high school students focused on the value of the technical content delivered.

Q1. Did you learn about microscopy and how it is used in science from the microscopy module?

Q2. Did you learn about technology and the different tools that are used in research during the AMP Tour?

Q3. Did this event increase your understanding of science?

The student responses from the above listed questions are organized in a chart in Figure 3 (see following page). The results from the three separate survey questions indicate the students experienced an increase in their STEM knowledge through the experience. There was one student that stated there was *not much* increase in their knowledge of microscopy. The microscopy module was very new in the way it was delivered. That module was a true pilot, and prior to delivering

we were a bit concerned as the module required the students to observe ceramics from a wide range of lengths scales (optical to SEM to TEM). Although there was one negative answer, the module was deemed a success based on the responses.

The biggest positive responses from the students that we received was that **100%** of the students stated that they would *somewhat* or *very much* recommend the program to a friend.

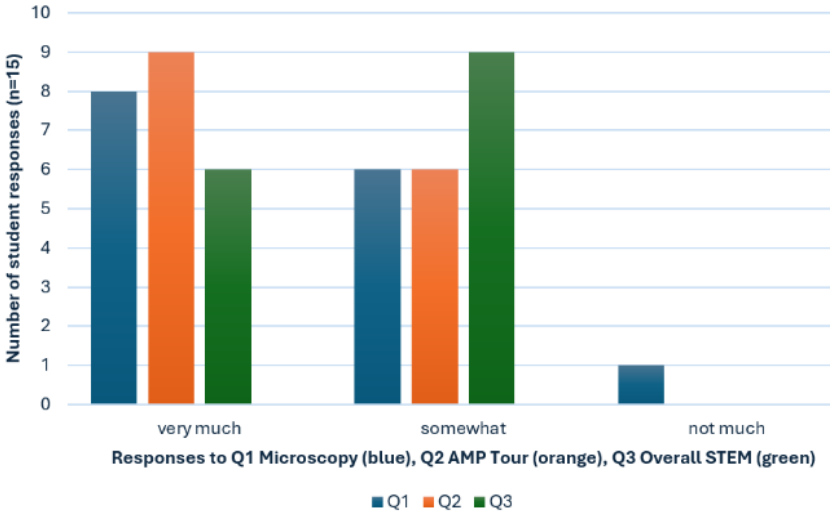

Figure 3: Student responses to the A+E program survey provided after completion of the program.

Conclusion

The team at SDM successfully developed a curricular program for high schoolers that aligns with the SD Learning Objectives and provides students an opportunity to see and use state of the art equipment and technology at the institution. From the survey results, the high school students had an overall positive STEM learning experience and would recommend the program to a friend. For the future, the curriculum and content will continue to be developed.

Citations

1. P. W. Stoffer, "Department of the Interior; U.S. Geological Survey," U.S. Department of the Interior, Menlo Park, CA, pp. 5–7. [Online]. Available: https://pubs.usgs.gov/of/2003/0035/pdf/of03-35.pdf.
2. South Dakota Education Association, "Learning Objectives Chemistry," [Online]. Available: https://www.sdea.org/sites/sdea/files/2023-12/hs-chemistry-2-slo.pdf. [Accessed: Jun. 24, 2024].
3. K. J. Donovan, J. J. Kellar, M. West, S. D. Kellogg, W. Cross, and C. M. Birrenkott, "Board 326: Investigating Creativity, Confidence, and an Entrepreneurial Mindset through Curricular Modification and Community Engagement," presented at the 2023 ASEE Annual Conference & Exposition, Jun. 2023.
4. K. Donovan, J. Kellar, M. West, C. Birrenkott, S. Kellogg, D. Mitchell, and M. Whitehead, "Investigating the Impact of Arts on Student Learning by Introducing Glass Science in the Materials Engineering Curriculum," presented at the 2022 ASEE Annual Conference Proceedings.
5. K. J. Donovan, J. Kellar, M. K. West, C. M. Birrenkott, M. Whitehead, S. Kellogg, and D. Mitchell, "South Dakota Mines Art + Engineering engagement in co-curricular and community focused events," presented at the 2024 ASEE Annual Conference Proceedings.