SOUTH DAKOTA MINES
An engineering, science and technology university

Investigating the Impact of Arts on Student Learning by Introducing Glass Science in the Materials Engineering Curriculum

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Introduction

The research for the *Investigating the Impact of Arts on Student Learning by Introducing Glass Science in the Materials Engineering Curriculum* involves the creation of an academic program (curricular and co-curricular components) that integrates art concepts into an undergraduate Metallurgical Engineering program at South Dakota Mines. The goals of the program are increased student innovation, creativity, collegiality, and entrepreneurship, all while broadening the undergraduate talent pool. The programmatic elements are focused on integration of arts in STEM (i.e. STEAM) to achieve the goals.

The centerpiece is the infusion of STEAM content into laboratories and courses distributed throughout the model engineering program in Metallurgical Engineering. A particular focus is the integration of STEAM into the upper-level capstone design sequence. Curricular modifications will be facilitated through involvement of a resident artist who is embedded within the academic program.

Curricula Integration

The **initial** phase of programmatic elements began in the Fall of 2021 with the integration into Structure and Properties of Materials Lab (MET 231) and Introduction of Metallurgical Engineering (MET 110). For the MET 110 course, a first-year student group, the first year Metallurgical Engineering students had a sketching module which then translated to a crystal structure module and a 3D Printing module. In MET 110, the students also created glass pendants (Figure 1), learned welding techniques and casted artistic aluminum pieces.

For the MET 110 course pre- and post activity surveys were completed with questions focusing on self-efficacy in topics relating to creativity, metallurgical knowledge, and anxiety related to completion of a kinesthetic learning opportunity. Self-efficacy is an individual's belief in his or her capacity to execute behaviors necessary to produce specific performance attainments.[1]

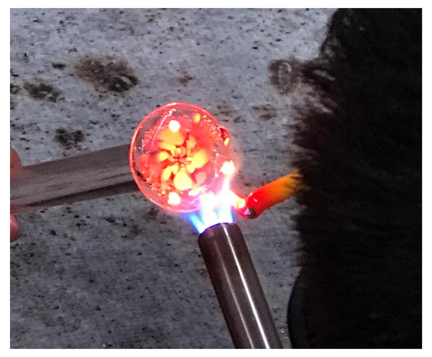

Figure 1: MET 110 student integrating color into the clear glass

Figure 2 is a graphical representation of the MET 110 student responses (n=18) to a creativity question, note that the left-hand side of the x-axis represents no truth with regard to a self-efficacy statement and the righthand side of the x-axis represents an exact truth. For the creativity question, the students were asked to respond according to the following prompt, "*I think of myself as an individual with creative skills.*" For the metallurgical question, the students were asked to respond according to the following prompt, "*I think of myself as an individual that is expertly knowledgeable about metallurgy.*"

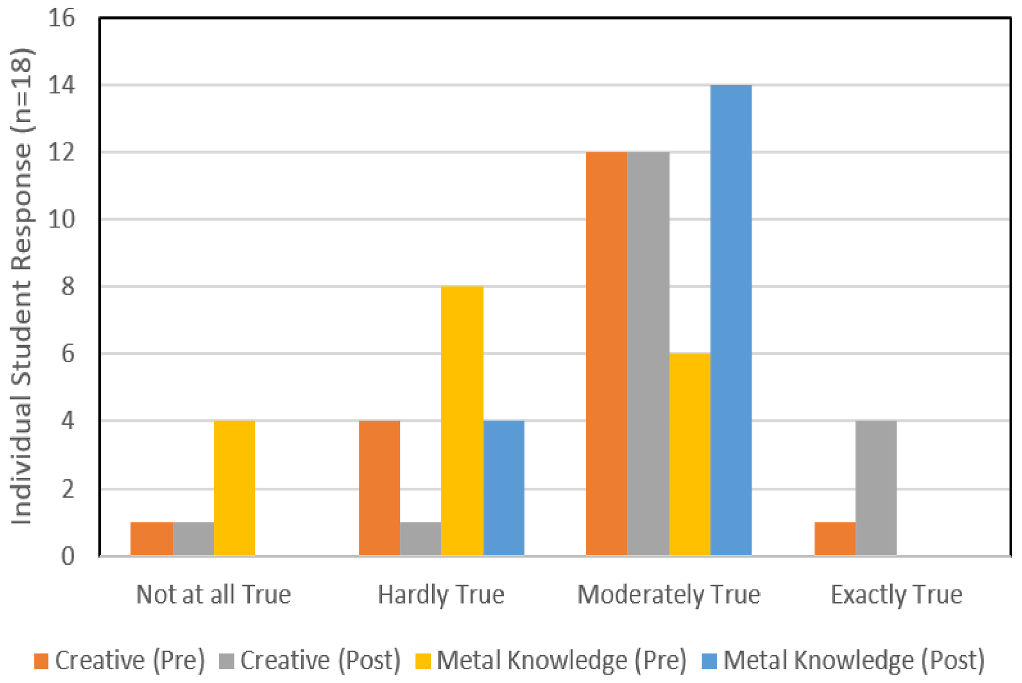

Figure 2: The pre- and post response represent their feelings at the beginning of the term (pre) and at the end of the term (post).

An overall positive trend of improved self-efficacy can be seen for both the creative skills as well as the technical (metallurgy) knowledge. Twelve students at the beginning of the term rated themselves at the lower end of the spectrum for their Metallurgical knowledge. At the end of the term, 14 students reported on the upper end of the data, with a majority in the "Moderately True."

The **next** phase of programmatic element integration was focused on a junior level course, MET 352 Principles of Metallurgical Design. To date, the most successful and complete integration of our program initiatives has occurred in Metallurgical junior design course (MET 352).

Faculty Engagement: Design teams were formed with a faculty lead (each of whom gave a technical talk on their area of expertise) and all students had a ceramic body creation and processing kinesthetic lecture with the Artist-in-Residence.

Acknowledgements: Thanks to South Dakota Mines Materials and Metallurgical students and faculty. This work was made possible through the National Science Foundation NSF IUSE Award #2120156.

Design Approach

***Student Design Objective**: Design the processes and materials to develop a clay-based ceramic product using Black Hills resources (minerals). The base material should be used to create a ceramic pottery piece as proof-of-concept for the design (Figure 3).*

Considerations:

- The type of ceramic pottery (e.g. earthenware) created will be chosen by the design team.
- The minerals will be characterized by x-ray diffraction prior to the start of the project, and each team will be responsible for any mineral processing (crushing, grinding, particle sizing, etc.).
- The final design should include all the materials, forming and processing conditions (e.g. wt% of minerals, order of processing, times and temperatures) required to produce a final demonstration piece.
- Other considerations include availability of materials, ease of processing, toxicity of materials used and piece aesthetics.
- The course will culminate in a competitive assessment of the final clay-based ceramic piece with emphasis on product design difficulty, execution of final piece, and creativity of the design process and product.

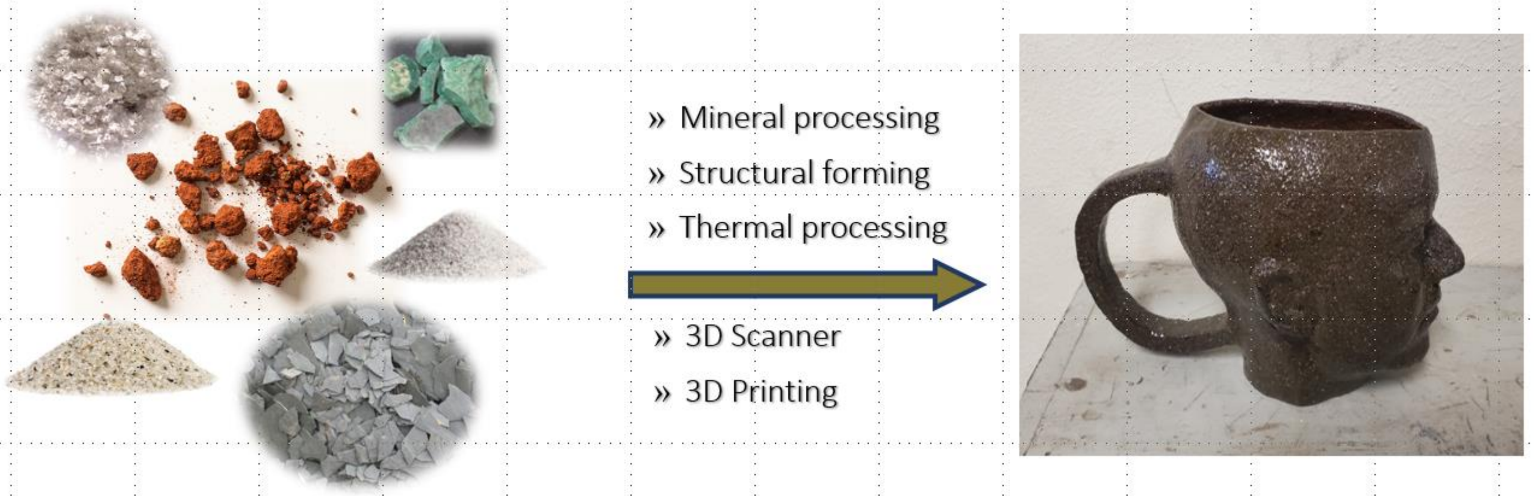

Figure 3: Modified image from a MET 352 final presentation representing the goal of designing a unique product from minerals that must undergo multiple processes and leverage technology to produce a complex ceramic body as seen above.

MET 352 has some key components that students learn during the course. One component is the importance of a roadmap (Design Methodology) for the project (see Figure 4). This roadmap assists with the iterative nature of design (see Figure 5). Finally, the teams optimize a design to understand and illustrate when different aspects of design can be tested simultaneously.

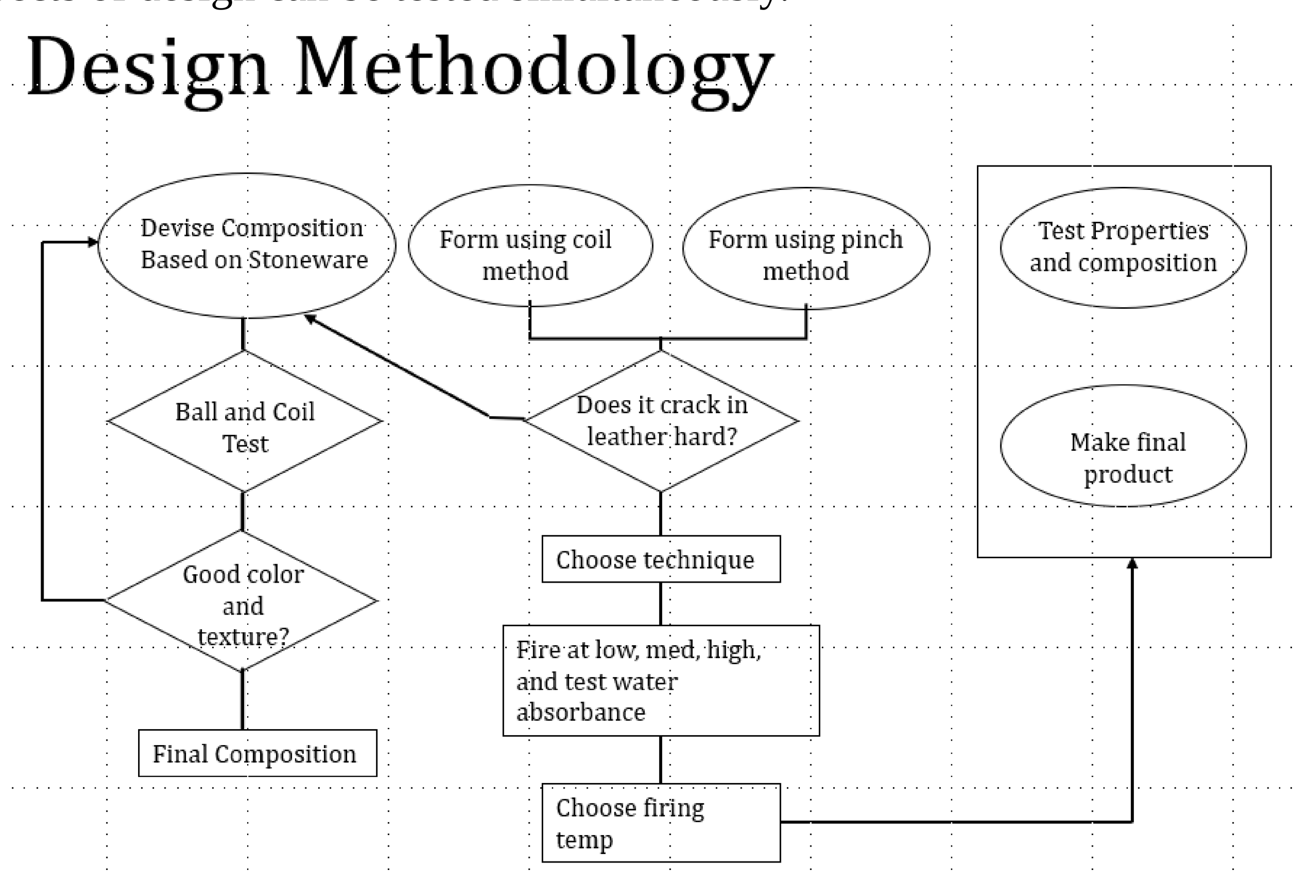

Figure 4: Image from a MET 352 team's final presentation representing a team's example design approach. The simultaneous processes and iterative nature are illustrated on the left-hand side.

Figure 5: Image taken from another MET 352 team's final presentation that demonstrates the optimization process of modifying a specific aspect of the design process to produce a high-quality product.

Results

The MET 352 teams successfully created a unique ceramic product formulated from Black Hills clay, which included a novel glaze formulation, see Figures 6 and 7.

Figure 6: Image from a MET 352 team's final presentation showing the team's muse, Dr. Michael West the Materials and Metallurgical Engineering Department Head, and the ceramic mug that team designed to be a coffee mug replica of his head. (coffee mug also shown in Figure 3).

Figure 7: Image from a MET 352 team's final design presentation. The students made a mold around a statue of South Dakota Mines mascot, 'Grubby'. The students slip cast into the mold, fired the clay body (image on right), glazed the body, and then acrylic painted (image on the right) the ceramic body.

Conclusions

In MET 352 the STEAM integration of artistic/mineral processing focus was very successful. The students comminuted (crush, grind, classify) various clay bodies to characterize the components of the clay body. The students used scientific resources (e.g., x-ray diffraction) to optimize their formulation. Faculty delivered new course modules on *i)* minerals for ceramics *ii)* rheology of clays and *iii)* fluxes, glazes and vitrification.

In MET 231, the student successfully completed a Metal Clay (a combination of micron-sized metal particles and cellulose) module Prior to firing the artistic piece, the Metal clay body "green body" was formed by the students. The green body sculpture developed is unique for each student, facilitated through interactions with the program's Artist in Residence. The success of this lab was also translated to a teaching module presented at the South Dakota High Science and Math Teachers Conference.

The MET 110 course successfully integrated multiple hands-on curriculum that improved the first-year student self efficacy related to a variety of engineering skills from drafting to casting to glass working and more.

The next steps for the team include further engagement with the community.

[1] A. Bandura *Self-efficacy: The exercise of control.* W H Freeman/Times Books/ Henry Holt & Co. 1997.