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# Integrating Professional Mentorship with a 3D-Printing Curriculum to Help Rural Youth Forge STEM Career Connections

**Miss Srinjita Bhaduri, University of Colorado Boulder**

Srinjita Bhaduri is a PhD candidate in Computer and Cognitive Science at the University of Colorado Boulder. Her research examines how educational technology can improve student engagement and student learning, often focusing on underserved populations.

**Dr. L. Lee Biddy, University of Colorado Boulder**

Dr. Quentin Biddy is a Research Associate in the Institute of Cognitive Science. He is currently working with the iHUB and Schoolwide Labs projects researching and developing open source resources to support high school and middle school science teachers transitioning to Phenomena-Driven, Three-Dimensional Learning and assessment aligned to the NGSS. Through his work with the Schoolwide labs project, he is focusing on supporting middle school science teachers intentionally integrating Computational Thinking Practices into students' learning experiences through co-designed CT integrated NGSS aligned storylines. His research/work experience and interests focus on effective science learning and teaching, Phenomena-Driven learning, NGSS aligned 3D Learning and formative assessment, CT integration, Pedagogical Content Knowledge, teacher professional learning, and the Nature of Science and History of Science in science education.

**Melissa Rummel, University Corporation for Atmospheric Research**

Educational Designer

**Dr. Jeffrey B. Bush, University of Colorado**
**Jennifer Jacobs, University of Colorado Boulder**

Dr. Jennifer Jacobs is an associate research professor at the Institute of Cognitive Science at CU-Boulder. Dr. Jacobs has served as the PI or Co-PI on a variety of funded studies spanning mathematics and science education, with a particular focus on the development of curricular and professional learning resources for teachers and their impact on classroom instruction and student learning.

**Mimi Recker, Utah State University**
**Mr. John Daniel Ristvey Jr., University Corporation for Atmospheric Research**

John Ristvey, M.S., (UCAR, Principal Investigator), is development lead for Engineering Experiences in collaboration with Dr. Tammy Sumner, Srinjita Bhaduri, and Dr. Randy Russell. He provides expertise in Out of School Time (OST) programming with student supports and STEM education. Ristvey coordinates each of the teams and lead the design team as well as the work of the advisory board. He has conducted extensive research and development work in STEM OST projects such as Cosmic Chemistry (Institute for Educational Sciences, Department of Education) and NanoExperiences. Ristvey was the PI for three NSF-funded projects: NanoLeap, NanoTeach and NanoExperiences. He also was the lead developer for the Dynamic Design series of engineering modules for NASA's Genesis mission. He holds a Master's degree in Secondary Science Education from University of Houston, Clear Lake, TX.

**Dr. Alexandra Gendreau Chakarov, University of Colorado Boulder**

Dr. Gendreau Chakarov received her Ph.D. in Computer Science and Cognitive Science from the University of Colorado Boulder in 2020 where she examined how to integrate computational thinking into middle school science curriculum using programmable sensor technologies as part of the SchoolWide Labs project. She continues this work on the SchoolWide Labs Project as a research associate where she serves as the computer science and computational thinking specialist.

**Prof. Tamara Sumner Sumner, University of Colorado Boulder**

I am a Professor at the University of Colorado, with a joint appointment between the Institute of Cognitive Science and the Department of Computer Science. I am currently serving as the Director of the Institute of Cognitive Science. I lead an interdisciplinary research and development lab that studies how computational tools – combining cognitive science, machine intelligence, and interactive media – can improve teaching practice, learning outcomes and learner engagement. My research and teaching interests include personalized learning, learning analytics, cyberlearning environments, educational digital libraries, scholarly communications, human-centered computing, and interdisciplinary research methods for studying cognition. I have written 140 articles on these topics, including over 80 peer-reviewed scholarly publications.

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## Introduction

Youth residing in mountain tourist communities represent an important and underserved rural population. Science, engineering, and computing are hidden within the daily workforce practices in these communities, unlike large metropolitan areas where technology jobs are prominent in the local culture. Youth in rural communities may think that Science, Technology, Engineering, and Mathematics (STEM) careers require them to leave their communities, which can disincentivize academic preparations [1, 2]. Youth career experiences through in-school and out-of-school programs are often general in nature, and not tied to youth's other learning experiences [3]. Youth may be challenged to understand how these career experiences relate to their lives. Attrition of youth from middle-school programs is particularly troubling as middle school is a period in which many students lose interest in STEM and achievement gaps begin to widen [4]. Evidence suggests that disadvantaged youth are not fully participating in available career experiences, leading to unfilled science and computing-oriented internships [5]. This research presents initial findings from a pilot study of an innovative model involving working with local schools and community partners to support the integration of local career contexts, engineering design challenges, career connections, and mentorship into a 3D printing curriculum to motivate and increase interest for rural youth for future STEM careers. Preliminary data analysis suggests that the relationship between local STEM businesses and students is important to help motivate rural youth to see themselves being successful in STEM careers and can help them to realize the benefits of engaging with engineering technologies.

## Context

In Fall 2020, we worked with two western US rural mountain middle schools. Due to school district pandemic regulations, teachers Eva and Sean (Pseudonyms) taught four days in-person (one-hour long sessions) with one day for asynchronous learning and lesson planning. Members of the research team provided remote/virtual curriculum resources, research instruments, and ongoing support in the form of weekly video calls and other communication. We designed a 3D printing curriculum using an instructional design approach called storylining [6], to promote coherence, relevance, and meaning from the students' perspectives by using students' questions to drive the lessons. Students solved the question: "*How can we support animals with physical disabilities so they can perform daily activities independently?*" They engaged in the engineering design process to develop and print prosthetic limbs for animals with disabilities using 3D modeling and printing. To embed connections to STEM careers, selected students received mentorship from a local STEM organization with a long history of outreach within the community. Eva's students submitted an interest form, while Sean selected his 5th-period students to participate. Meetings with the organization and teachers resulted in a structure for student-mentor experiences that met both teacher and mentor goals. A low student-mentor ratio was important to the partner organization, as was working with students who were invested and interested in the interactions.

*Participants:* A total of 214 8th graders participated in the 3D printing unit and of these students, 14 from Sean's classes and 12 from Eva's classes also participated in the mentor experience (see Table 1). STEM professionals (n=12) from a local orthopedic sports medicine research organization worked with the students twice remotely, due to the pandemic, during the 3D printing unit to provide feedback on their 3D prosthetics, discuss connections between their work and what the students were doing in class, and talk about related career paths.

Table 1. Demographic Information of Students Participating in Mentoring Experience

| Teacher | Students | Gender | Home Language | Ethnicity* | # Interviewed |
|---|---|---|---|---|---|
| Sean | 14 | F - 57%<br>M - 43% | Spanish - 14%<br>English - 86% | Hispanic/Latin@ - 29%<br>Native American/Alaskan, Pacific Islander - 14%<br>White/Caucasian - 79% | 2 |
| Eva | 12 | F - 25%<br>M - 75% | Spanish - 33%<br>English - 75% | Hispanic/Latin@ - 58%<br>African American - 0.8%<br>White/Caucasian - 42% | 2 |

*Students were able to select multiple categories (e.g. all that apply)

*Data Sources*: The teachers nominated a set of students (n=16) to participate in pre- and post-STEM interviews with a member of the research team. Of these 16 students, four also participated in the mentoring experience. The interviews (conducted remotely) focused on students' career interests, understanding of what STEM entails, and reflection about the 3D printing unit. Students (n=214) completed a STEM Interest survey consisting of four sets of questions, each set focusing on one element of STEM. Students took this survey twice, once at the start of the quarter (pre) and once at the end of the quarter (post). The survey was taken verbatim from Kier et al. (2013) [7] with eight additional negatively worded questions to check for response consistency. Additionally, following each mentoring session, students (n=16), mentors (n=12), and teachers (n=2) completed a short reflection survey. Student surveys involved thoughts on the mentoring experiences, their STEM learning, and suggestions for improving the experience. Mentors reflected on motivations for volunteering, experience participating, and suggestions for improving the experience. Teachers reflected on students' engagement in the mentoring experience and how it impacted student engagement with the 3D printing unit. The mentoring experiences were conducted remotely and recorded. At least one researcher observed and took notes about the mentor-student interactions in each breakout room.

*Analysis:* The research team used an open coding approach to analyze the qualitative data (i.e., interviews and open-ended surveys) to determine what themes emerged from the student-mentor interactions [8, 9]. For the quantitative data, only matched responses to both the pre and post survey were analyzed. The negatively worded survey questions were used to uncover inconsistencies in students' responses. These responses were excluded from the analysis. After cleaning, the data from ten mentored students and 81 non-mentored students remained.

## Findings

*Student perception of STEM and STEM careers:* During the pre- and post-STEM interviews most of the students were able to tell what STEM meant (i.e., Science, Technology, Engineering, and Math), however when asked, "what STEM jobs are there in your community?" many were unable to identify any STEM jobs. When asked if they knew someone who had a STEM job some students stated ideas such as: maybe my teacher, or my [parent] does construction, is a mechanic, is an electrician, or works in real estate, etc. Analysis of the matched STEM interest survey responses reveals that most survey items showed no noticeable increases or decreases, with one notable exception. When asked if they plan to use science in their career, mentored students' post-survey responses were higher on average by 0.67 points (one point corresponding to one increase on the Likert scale) compared to their pre-survey responses and showed no significant change for non-mentored students. While small, a t-test shows that the difference in gain scores between mentored ($M=0.6$, $SD=0.96$) and non-mentored students ($M= -0.07$, $SD=0.70$) was statistically significant ($t\ (89) = -2.73$, $p<0.01$) and the magnitude and significance remained even when controlling for gender, teacher, and ethnicity (see Figure 1).

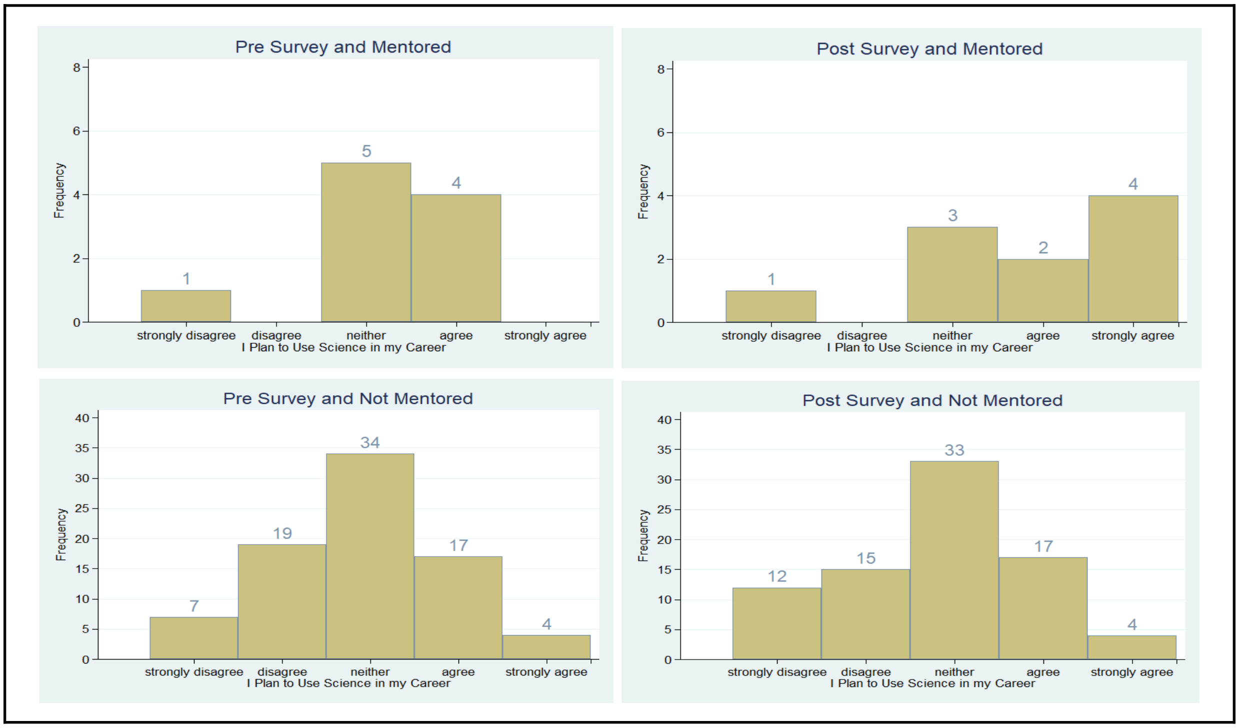



Figure 1: Histograms showing the distribution of mentored and non-mentored student Likert responses on the pre and post survey to the question, "I plan to use science in my career."

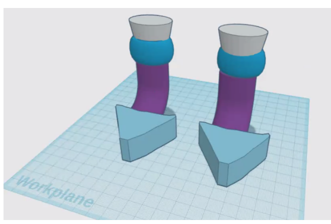
During the mentor experiences, some students made connections between the 3D printing unit and the mentors' careers. In the excerpts from the breakout room conversations below, students learned why mentors pursued a STEM career and how STEM involves creativity and flexibility.

*Breakout Room Excerpt 1*
M: What is the most exciting thing about this project?
S1: We get to create an invention to help out animals.
S2: I like designing my own thing without restrictions.
M: I like that about my job as well.

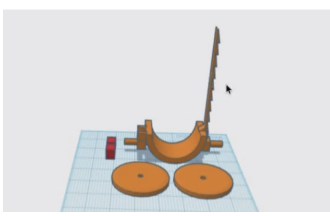
*Breakout Room Excerpt 2*
S: What got you into STEM?
M: I like math and science. The cool thing about engineering is you can make an impact...biomedical fields can make an impact with products and research.

*Need for introducing STEM mentors in K-12 education:* Our data analysis suggests that students who participated in the mentoring program overall enjoyed the opportunity to meet STEM professionals and learn about their jobs. They valued the open discussion format and the opportunity to talk about their projects to "get answers, feedback, and helpful advice." One student noted, "[I liked] that it was mostly up to the students on what we talked about."

Mentored students reported they now know more about STEM jobs, feel having a mentor can help them, and are better at explaining their ideas and asking questions. Mentors also shared a positive assessment of the experience. One mentor responded, “The most rewarding part was working through the design of their prosthetic with [the students].” Students were able to share their screens to show and discuss their 3D prosthetic designs and problems they encountered (see Figure 2). This provided opportunities for students to troubleshoot issues they encountered with STEM professionals in a related field. The teachers noted positive reactions to the student-mentor experiences. Eva stated that mentoring provided a valuable “out-of-school” experience for students during a time when most enrichment activities were not available. Sean noted that one student who often struggles in the classroom “...was really engaged, this was [his] day to shine.” The teachers felt that it was important for students to make connections to STEM jobs in their community, and to expand career awareness beyond working at the ski resorts (a large employer in the region). They saw students using ideas from the meetings to inform their prosthetic designs. One student suggested that “...working on our projects while in the meeting so [the mentors] could help us along the way,” would make the meetings more helpful and fun. Mentors kept ongoing communication via emails with their students to share concepts and ideas.




M: Can you describe the design?
S1: Purple parts can be tubes or flexible parts.
M: You are making pyramid shaped feet?
S1: Still figuring out, could be a human foot.
M: Did you have something that is still challenging?
S1: I know you have done this and will know better, how to make feet for the animal?
M: So, like the foot part and like what you want to do?
S2: Shares about the shapes used on tinkercad.



S: I didn’t know how to attach it to the animal so I made a zip tie type strap.
M: So, it's a one size fits all type thing?
S: Yes, here are the pegs to attach the wheels.
M: You did your project in clay first, did you make changes?
S: It's been smoother, with clay it wasn’t proportional, the wheels were oval and it was uneven. I didn't have a way to keep the wheels from falling off.
M: That's how you came up with the pegs and superglue?

Figure 2. Students’ 3D prosthetic designs shared during student (S) - mentor (M) meetings

**Discussion and Future Work**

Our preliminary findings suggest that disadvantaged youth are not able to identify the STEM careers available to them in their local community and tend to have a misconception of what STEM careers entail, often referring to jobs that minimally use only one element of STEM as being a STEM job. The mentored students had a better notion of what STEM careers are and by the second meeting were better able to communicate their projects with the mentors. Through the mentoring experience, students had opportunities to discuss their projects with the STEM professionals. Mentored students had a more positive view of science and the possibility of using science in their future careers. With a more structured approach to integrating mentoring over a longer period of time, we would expect to see these impacts across more students and would foresee them extending to students’ perceptions of Technology, Engineering, and Math as well [1, 2, 5]. We recommend including mentoring experiences with STEM professionals in curricula related to emerging technologies, engineering, and science, particularly for students from rural communities. Through these intentional STEM interactions that connect students to STEM in their immediate community, students can gain awareness of local STEM career opportunities and career pathways. Moving forward we plan to include guidance to add more structure to student-mentor meetings, with students prepared to ask specific questions about their STEM projects, and timing the meetings to align with relevant classwork. We encourage spending more time developing the student-mentor relationship and increasing interactions for students to collaborate with mentors and share finished products. Finally, we propose that the mentoring opportunity be available to all students participating in the curriculum to support a more equitable learning environment.

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