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Modernizing the photogrammetry curriculum by integrating the entrepreneurial mindset, bio-inspired design and STEAM approach

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Abstract

Purpose – Photogrammetry enables scientists and engineers to make accurate and precise measurements from optical images and other patterns of reflected electromagnetic energy. Photogrammetry is taught in surveying, geomatics and similar academic programs. For a long time, it has been observed that there is a lack of diversity and underrepresentation of different groups in the surveying and geomatics workforces for various reasons. Diversity fosters more innovative environments, helps employees be more engaged and boosts productivity rates. Although efforts are being made to solve this problem, most attempts did not significantly improve the diversity issues in this field. To address this problem, we designed a new curriculum for a photogrammetry course, which integrates entrepreneurial mindset (EM), bio-inspired design and Science, Technology, Engineering, Arts and Mathematics (STEAM) into the photogrammetry course for this study.

Design/methodology/approach – In this study, the participatory action research method, Photovoice, was used to gather data. Students were asked to respond to photovoice and metacognitive reflection prompts to understand student perceptions about the importance of Unmanned Aerial Vehicles (UAVs) in photogrammetric mapping. Students were required to respond to each prompt with three pictures and a narrative. These reflections were analyzed using thematic analysis.

Findings – The analysis of the photovoice and metacognitive reflections resulted in six themes: promoting digital literacy, promoting job readiness and awareness, improving perceived learning outcomes, increasing interest in pursuing careers in surveying/geomatics, encouraging learner engagement and increasing awareness of the role of art in map making.

Originality/value – This is the first study conducted at our Hispanic Serving Institution, which specifically designed a curriculum integrating EM, bio-inspired design and STEAM concepts to address diversity issues in surveying and geomatics engineering disciplines.

Keywords Photogrammetry, Geomatics, Metacognitive reflections, Diversity, unmanned aerial vehicles (UAVs), Entrepreneurial mindset, Bio-inspired design, STEAM

Paper type Research paper

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Diversity is the practice of including people from different races, genders, ethnicities, and backgrounds (Servaes *et al.*, 2022). Geomatics, formerly surveying engineering, is part of the bigger umbrella of geospatial engineering, also known as geosciences/geoinformatics (Ajvazi *et al.*, 2016; Deren, 2017). This engineering field is essential for economic and sustainable development (Gong *et al.*, 2017). The engineering and education professions in the US face a diversity shortage, as most students are predominantly white males (Eastman *et al.*, 2019). This highlights a clear deficit of racial and ethnic minority students enrolled in engineering education, and the field is essential for economic and sustainable development (Gong *et al.*, 2017). The geospatial field is part of engineering that faces a diversity problem (Dutt, 2020). Despite the rapid growth of jobs created yearly in the geospatial field, it lacks a diverse workforce. The geoscience workforce has a large diversity gap, particularly in the United States (Joyce *et al.*, 2021) and other countries (Abe, 2021; Handley *et al.*, 2020; Piccoli and Guidobaldi, 2021). Historically, geomatic professionals have been known to be white males and geomatics engineering is regarded as the least diverse field (Bernard and Cooperdock, 2018). This problem results from a lack of diversity in geoscience and geomatics education (Belgiu *et al.*, 2015). If the diversity problem in geosciences continues to exist, the geospatial field will have no heterogeneity, leading to a workforce environment that is less accessible, inclusive, and equitable to everyone (Foma, 2014). Building a diverse environment will bring a variety of knowledge and skills that will increase productivity, leverage ideas, and boost experiences in the workplace.

Current approaches and gaps

Different approaches and attempts have been carried out to address diversity in engineering in general and in the geospatial field (Baber *et al.*, 2010; Huntoon and Lane, 2007; Wechsler *et al.*, 2005). First, the establishment of minority-serving institutions. These institutions serve a significant number of students and offer a variety of degrees. However, the literature does not show much research analyzing how establishing these intuitions helped increase diversity in geomatics. Second, the diversity and inclusion initiatives. Guhlincozzi and Cisneros (2022) proposed to build a community collaboration initiative through a camp for middle school girls. Women of color helped as counselors, and recruitment occurred during the camp.

Similarly, Vila-Concejo *et al.* (2018) focused on increasing gender diversity in coastal geoscience and engineering. They suggested practices such as advocating for more women in the field, promoting high-achieving females, and providing better support. While such initiatives are tremendous and offer opportunities for women, yet, most of these practices are focused on gender diversity only and have not shown significant improvement in solving the gender diversity issues in the geospatial field, as there is still a lack of women's representation in the geoinformatics field (Stout, 2022).

Another initiative that the National Science Foundation funded included five pilot projects to increase diversity, equity, and inclusion in the geoscience field. In these projects, participants came up with ideas such as community engagement, fieldwork, and mentoring to increase diversity in the geospatial field (Posselt *et al.*, 2019). Although these initiatives help promote diversity and equity in STEM fields, they focus more on providing general diversity resources and less on providing culturally responsive curricula for the STEM classroom. Most of the recommendations in these studies did not show significant improvement in solving diversity problems over the past two decades. While geosciences have the least racial and ethnic diversity of STEM fields, little research has been done to overcome this problem. While ethnic diversity is essential for promoting social unity, inspiring cross-cultural knowledge, and fostering inclusive understanding, limited literature suggests that very little has been done to increase ethnic diversity in the geoscience field.

Proposed solution

This study implements a newly developed curriculum in response to the lack of diversity in the geomatics field. The curriculum introduced an interdisciplinary project in a photogrammetry course that includes concepts pertaining to the Entrepreneurial mindset (EM), Bio-inspired design, and Science, Technology, Engineering, Arts, and Mathematics (STEAM). This study aimed to analyze students' perceptions of a newly designed curriculum in one course of the geomatics program at our Hispanic-serving, Southwestern research-based institution. We used the following research question for our study:

RQ1. What are the lessons learned from implementing an Entrepreneurial Mindset, Bio-inspired design, and STEAM-infused curriculum into a photogrammetry course?

Background

The following sections give a brief overview of (1) geomatics engineering, (2) photogrammetry, (3) the entrepreneurial mindset (EM), (4) bio-inspired design, (5) Science, Technology, Engineering, Arts, and Mathematics (STEAM), and (6) Study Intervention.

Geomatics engineering

Geomatics, formerly known as surveying engineering, is part of the more extensive umbrella of geospatial engineering, also known as geosciences/geoinformatics (Ajvazi *et al.*, 2016; Deren, 2017). This engineering field is essential for economic and sustainable development (Gong *et al.*, 2017). The geospatial field is part of engineering that faces a diversity problem (Dutt, 2020). Beane *et al.* (2021) showed only an increase from 3% to 10% in the number of bachelor's degrees received in geoscience by Hispanic/Latino students from 1998 to 2018. They reported a stable ratio for Black/African American and Asian American students. An earlier study at four institutions showed that only 10% of geomatics graduates were female (Mohamed *et al.*, 2011). Moreover, the targeted students in two surveying programs in the US showed that most students (87%) are male, 93% are white or Caucasian (Bolkas and Gouak, 2020), 13% were female, and only 7% identified as black/African American, Asian/Pacific Islander, or Hispanic/Latino at both the associate and baccalaureate degrees. Stokes *et al.* (2015) showed that several sociocultural factors obstruct diversity in geoscience, such as cultural disconnects, unsupportive families, and low outdoor experiences. The study included 926 "critical incidents" and interviewed 31 geoscience students and graduates (18 women, 13 men; 8 Hispanics, 21 whites) at a large university in the southwestern US.

Photogrammetry

According to the American Society for Photogrammetry and Remote Sensing, photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting imagery and digital representations of energy patterns derived from noncontact sensor systems (The American Society for Photogrammetry and Remote Sensing, 1988). Current photogrammetric techniques produce Digital Elevation Models (DEMs), orthorectified images, and digital topographic maps. Several new tools are now available to collect photogrammetric datasets, primarily small Unmanned Aerial Vehicles (sUAVs) that weigh less than 55 lbs (Federal Aviation Administration, 2016). As a result, photogrammetric education should be modified with more emphasis placed on new measurement platforms, particularly sUAVs. Worldwide, there have been several attempts to incorporate sUAVs into photogrammetric courses as a new surveying tool (Kosmatin Fras and Grigillo, 2016; Shults, 2019; Wright *et al.*, 2018). However, most of these studies focused on advancing students'

technical skills and teaching students the advantages and disadvantages of using sUAVs for data collection. Moreover, these students did not report any feedback from students, nor did they investigate the design of a bio-inspired, STEAM, or entrepreneurial mindset curriculum.

Entrepreneurial mindset (EM)

Bosman and Fernhaber (2018) define EM as an "inclination to discover, evaluate, and exploit opportunities." Entrepreneurship education is tied to fostering creative skills that graduates will apply in real life (Kalyoncuoğlu *et al.*, 2017). Incorporating EM into the engineering classroom benefits students as graduates need not only to be technically prepared but also to possess professional skills that are the core of the entrepreneurial mindset (Jiatong *et al.*, 2021). These skills include communication, interpersonal, problem-solving, critical thinking, enthusiasm, commitment, and motivation (McEwen and McEwen, 2010). Additionally, incorporating EM into engineering curricula improves students' lifelong learning, provides an adequate understanding of the business environment, and helps students become more self-reliant (Pradhan *et al.*, 2022).

Bio-inspired design

Bio-inspired design is defined as applying knowledge gained from natural phenomena to get solutions for engineering problems and foster technical inventions and innovations (Hashemi Farzaneh, 2020). Recently, engineering educators have expanded the integration of their curricula to include bioinspired design at different levels to respond to the engineering industry's and professional society's requests (Nagel *et al.*, 2016). Integrating bio-inspired design into the engineering classroom benefits students by appreciating nature and creating more efficient, sustainable, and economical solutions to real-world problems (Rehmat *et al.*, 2022). Additionally, it inspires students to find economical, efficient, and sustainable solutions for technical challenges from nature (Nagel *et al.*, 2019). Besides being a powerful problem-solving approach, bio-inspired design is interdisciplinary (Snell-Rood and Smirnoff, 2023) and can be used to broaden participation and engagement from underrepresented groups, especially women, within engineering disciplines (Gencer *et al.*, 2020).

Science, technology, engineering, arts, and mathematics (STEAM)

STEAM is defined as integrating arts with STEM disciplines (Colucci-Gray *et al.*, 2019). Including arts in STEM disciplines points to the recovery of educational aims and purposes exceeding economic growth, for example, by embracing social inclusion, community participation, or sustainability agendas. Including STEAM in the engineering classroom stimulates students to understand the components of STEM education more straightforwardly and interestingly, supported by the principles of arts (Yuni and Bukit, 2021). It also improves students' imagination, creativity, and innovation skills (Rodier *et al.*, 2021).

Study intervention

The study focuses on students enrolled in the photogrammetry course of the geomatics program at the College of Engineering. The course is taught online in an asynchronous mode. This research explores how engineering students perceive bio-inspired, STEAM, and entrepreneurially minded coursework. Students were asked to write a technical report on new technologies and provide feedback on the newly developed curriculum [fusion of EM, Bio-inspired design, and STEAM concepts in the photogrammetry course].

The newly developed curriculum was given to the students as their first assignment, "Homework 1: Reflection on the importance and use of drones in surveying". Students were

required to work in teams of three or four, and the instructor assigned the teams randomly in Canvas. The learning goal of this assignment was to integrate the entrepreneurial mindset, bio-inspired design, and STEAM into the engineering classroom.

The assignment was divided into four steps and was conducted in the spring semester (Table 1). The assignment was graded out of 100 points. Step 1 had 12 points for the communication presentation and three points for gathering and implementing feedback from a friend or relative. Steps 2 and 3 carried 18 points in total, 15 points for the deliverable, and three points for feedback from a classmate [Step 2] and a professional surveyor/engineer [Step 3]. Step 4 was worth 50 points. The table below provides an overview of the newly developed curriculum.

For *Homework 1: Step 1: "Historical Perspective,"* students were asked to research the history of aerial mapping technology, focusing on how aerial mapping helped grow the surveying profession. Additionally, they were asked to research the history of aerial mapping and explain how biomimicry (e.g. birds) has played a role in the innovation process. Furthermore, the assignment also required students to research the history of cartography (the art of map-making) and how art influenced the map-making industry. For *Homework 1: Step 2: "How did drones develop and why?"*, students were asked to present their perception of the relationship between how birds fly and how engineers design drones. The assignment required students to share their opinions on how drones responded to the professional needs of surveyors in the past and their view of the future opportunities drones will provide to the profession. For *Homework 1: Step 3: "Comparing new and traditional mapping technologies,"* students were asked to compare and contrast drones in terms of maneuverability, range, and scale; compare and contrast the techniques of map-making and how maps are created and presented that influence how people react to them; interview a professional surveyor or engineer about the revolution of drones as used in surveying. For *Homework 1: Step 4: Student Learning Assessment*, students were asked to complete a Photovoice Reflection (Figure 1) and an Open-Ended Questions form (Figure 2). Additionally, students were provided with a list of Internet resources for reference and contact information of professionals (e.g. engineers and surveyors) for interviews in case they did not know any professionals in the geomatics field.

In this study, students were asked to provide feedback on the historical perspective of mapping, the development of drones, their importance to the surveying and engineering professions, and to compare new and traditional mapping techniques. Students reported their findings through an infographic, podcast, or video presentation. For student learning assessment, photovoice reflection and metacognitive reflection forms were administered to the students at the end of the project. Data was collected using a standardized assessment document and analyzed using a qualitative approach, thematic analysis.

Methods

This project was implemented at a Hispanic-serving institution that enrolls approximately 58% females and 41% males campus-wide. The College of Engineering enrolls approximately 24% females and 76% males. On average, at our university and within the College of Engineering, 60% of our students are Hispanic, 26% are White, and the rest are from other races and ethnicities.

Participants

The demographics of the class are similar to the general population. Most are non-traditional students (i.e. about 50% have finished an associate degree), have worked in the industry for a few years, and are returning to finish their baccalaureate degree. The majority of the students

Table 1.
Intervention framework

Learning objectives	Time	Assignment	Description	Deliverables
1 Students will know the history and impact of drone development on mapping practices 2 Students will understand that technological revolutions have an impact on mapping techniques and understanding our world 3 Students will be able to communicate at least one impact of drone development on mapping via an infographic, podcast, or video presentation (PowerPoint presentation to MP4)	3 weeks	Homework 1: Step 1: Historical Perspective	1 Research the history of aerial mapping technology with a focus on how aerial mapping helped grow the surveying profession. (Entrepreneurial mindset) 2 Research the history of aerial mapping over time and explain how biomimicry (e.g. birds) may have played a role in the innovation process. (Bio-inspired design) 3 Research the history of cartography (the art of map-making) and how art influenced the map-making industry. (STEAM)	Communication presentation + Gather feedback from at least one friend or relative
	1.5 weeks	Homework 1: Step 2: How did drones develop and why?	1 Relate between how birds fly and how engineers design drones (bio-inspired design) 2 Recognize how drones responded to the professional needs of surveyors in the past and the future opportunities drones will provide to the profession (entrepreneurial mindset)	Communication presentation + Gather feedback from peers or peer teams
	1 week	Homework 1: Step 3: Comparing new and traditional mapping technologies	1 Compare drone affordances based on maneuverability, range, and scale, for example, 3D imaging compared to satellite affordances (entrepreneurial mindset) 2 Comparing the techniques of map-making and how maps are created and presented influence how people react to them (STEAM) 3 Interview a professional surveyor or engineer about the revolution of drones as used in surveying	Communication presentation + Gather feedback from a professor and a professional engineer/surveyor
	1 week	Homework 1: Step 4: Student Learning Assessment	Photovoice Reflection Prompts + Open-Ended Questions	Respond to the Photovoice prompts and complete the Open-Ended Questions form

Student Assessment of Learning: Photovoice Reflection Prompts + Open-Ended Questions

Your answers should start here:

Part 1 - Photovoice Reflection Prompts (30 points: 10 points for the Photovoice reflection on each item: *4.5 points for the pictures (each picture 1.5 points), 1.5 for the captions (each caption 0.5 point), and 4 points for the narrative)*

*Photovoice Reflection Prompt A (**Entrepreneurial Integration**): The entrepreneurial mindset is defined as "the inclination to discover, evaluate, and exploit opportunities." Explain how participating in the newly developed curriculum integrated the entrepreneurial mindset, and lessons learned relevant to the entrepreneurial mindset.*		
<Insert Picture 1>	<Insert Picture 2>	<Insert Picture 3>
<Insert Caption 1>	<Insert Caption 1>	<Insert Caption 1>
<Insert Narrative (200 word minimum)>		

*Photovoice Reflection Prompt B (**STEAM**): STEAM (science, technology, engineering, arts, math) goes one step beyond the well-known STEM to acknowledge the importance of integrating the arts and humanities into more analytical coursework such as that found within engineering. Art can be incorporated through pieces, process, and movements. Explain how participating in the newly developed curriculum incorporated STEAM (specifically, the arts), and lessons learned relevant to STEAM (specifically, the arts).*		
<Insert Picture 1>	<Insert Picture 2>	<Insert Picture 3>
<Insert Caption 1>	<Insert Caption 1>	<Insert Caption 1>
<Insert Narrative (200 word minimum)>		

*Photovoice Reflection Prompt C (**Bio-Inspired Design**): Bio-inspired design uses the nature-focused context of sustainability, security, and/or biomedicine and health outcomes to motivate analogical thinking and improve the engineering design process. Explain how participating in the newly developed curriculum incorporated bio-inspired design and lessons learned relevant to bio-inspired design.*		
<Insert Picture 1>	<Insert Picture 2>	<Insert Picture 3>
<Insert Caption 1>	<Insert Caption 1>	<Insert Caption 1>
<Insert Narrative (200 word minimum)>		

Figure 1.
Photovoice reflection template

are residents of the state, but some are from out of state. The new curriculum was implemented in Spring 2023 in a photogrammetry course with an enrollment of 31 students. The course was split into two online sections: three sophomores, one freshman, eight juniors, and 19 senior students. Of the 31 students, 23 are majoring in geomatics, four are in civil engineering, three are in the civil engineering technology program, and one is in mechanical engineering. The class is required for all geomatics students and is offered as an optional elective for Civil Engineering Technology students and a general elective for other students.

Data collection

Data was collected using the standardized assessment document provided in Figure 1 for this study. This helped count the number of responses, provided anonymous feedback, and allowed the researchers to find and analyze themes in the qualitative analysis of the results. Students were asked to provide feedback on three prompts on how participating in this assignment incorporated the Entrepreneurial Mindset, STEAM, and bio-inspired design with a photovoice reflection of at least 200 words. In addition, students were asked to answer three

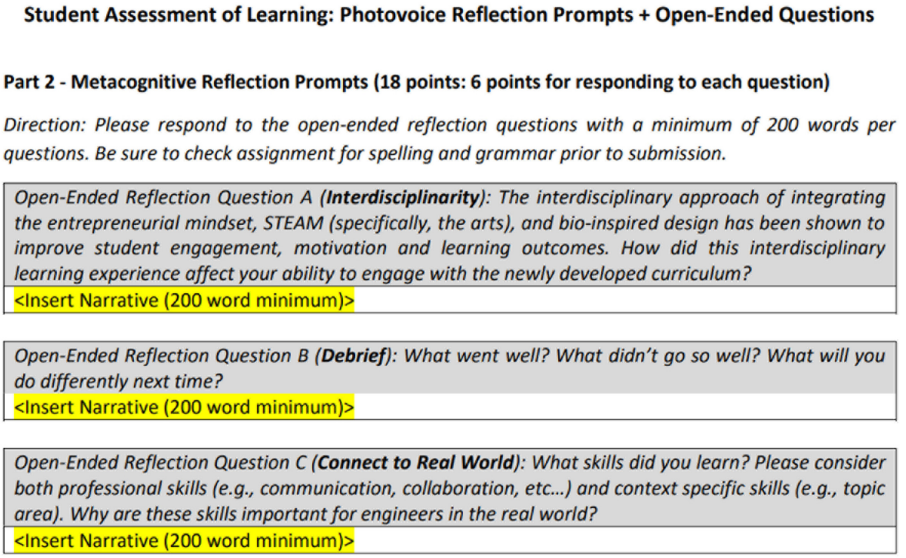

Figure 2.
Metacognitive reflection (open-ended questions form)

open-ended reflection questions with at least 200 words about the interdisciplinary approach of this assignment, a debrief about their learning experience, and the skills gained from the assignment (Figure 2). Students' responses were scattered between the different prompts and questions.

Data analysis

A qualitative approach, thematic analysis, was used to analyze the photovoice and metacognitive reflection data. Thematic analysis, as described by Braun and Clarke (2006), follows a qualitative method to find patterns within data and is implemented in a step-by-step manner. The data was analyzed by two authors who were familiar with the data to generate initial codes. After identifying the initial codes, the reflections were analyzed using NVivo 12, a qualitative analysis software, to find patterns and organize them into themes. Post-analysis, both authors exchanged individually identified themes and discussed each theme's strengths and weaknesses by including or removing participant quotes to provide readers with objective indications. Furthermore, participant quotes were captured and included in the results to allow the readers to discover their findings on accuracy, fairness, and credibility (Corden and Sainsbury, 2006).

Results

Analysis of the three photovoice reflections and three open-ended reflection questions provided us with the following themes: (1) promoting technology/digital literacy, (2) promoting job readiness and awareness, (3) improving perceived learning outcomes, (4) encouraging learner engagement, (5) increasing interest in pursuing careers in surveying and (6) improving awareness of the role art plays in map making. A visual representation of the summary of themes is provided at the end of this section (Figure 3).

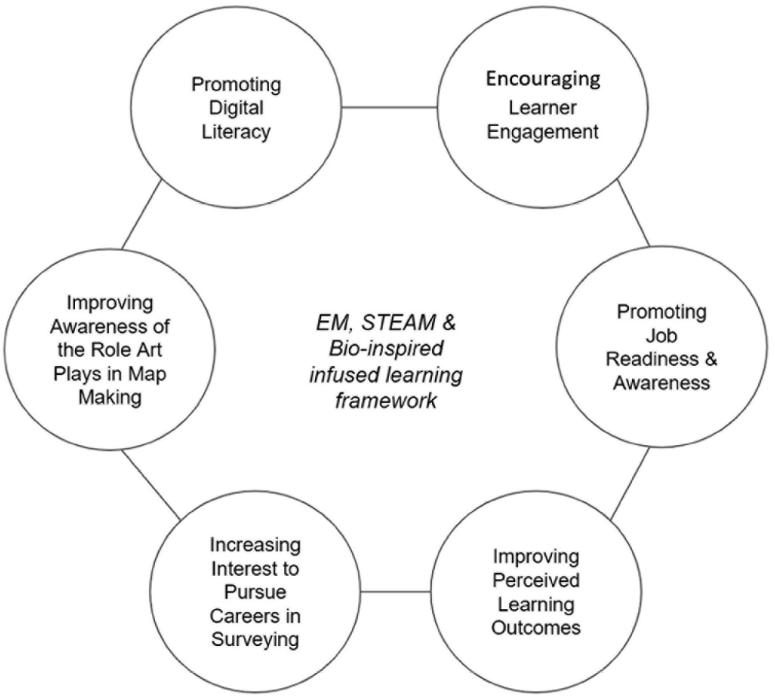

Figure 3.
Summary of themes

Theme 1: promoting digital literacy

After analyzing the quotes and statements submitted by students, it was found that the participants were not familiar with the technological tools being used in the newly developed curriculum. Participants acknowledged learning new technologies while completing the deliverables for the new curriculum. Examples of students' responses include:

(1) "I've learned to navigate through **Canvas** a little bit more. Overall, there is more to **learn tech** wise."

(2) "I was basically forced to **learn PowerPoint** very quickly, which I did, and I know that this continues to be a very useful skill to have in the working world. I'm quite thankful for that, as it was something I've wanted to learn, but never got around to doing. Also, just navigating the course and its platform has raised the level of my **computer competency** significantly."

(3) "We have a group **Microsoft Teams** chat going and I have learned to use the **calendar invite** function and make sure everyone replies to it to block time in their calendar and create an alert."

Theme 2: promoting job readiness and awareness

Students acknowledged the benefits of this assignment in improving their professional skills. They reported how they interacted with each other and how they enjoyed collaborating with other students. They stated that they were able to improve their teamwork and communication skills. They admitted they learned from each other. Most importantly, they

realized the importance of these skills in the engineering and surveying industries. Additionally, the participants were able to connect the newly learned skills to real-world job settings. Examples of students' responses include:

(1) "This project also showed how **project managers** must feel getting a lot of people together on the same page to be able to complete steps of the project together."

(2) "I have learned to **collaborate** with others and share ideas and to focus on what they say and take their criticism and learn from it. This assignment showed me to **express** ideas on how I can help the company expand into new concepts like drones which all ties back to the entrepreneurial mindset, where I have learned what new concepts can help the company I am in."

(3) **"Communication** is a huge skill that will definitely connect to the real world. During a **real world** project, you typically have a **project team** assigned, with each person possessing their own **specialty** of the topic or subject area. This approach to learning kind of simulates this, not only with communication but with **collaboration**, **scheduling**, **defining roles** based on knowledge or skill set, and many others."

(4) "While I was working on the **group project** in this lesson, I had to **collaborate with peers** in this class of different ages, ethnic backgrounds, and areas of dwelling. This will help me be able to work with so many different people in any future job opportunity I come across. I also **learned new types** of **communication** and how to incorporate time differences into collaboration."

(5) "This assignment helped me developed new skills. I also learn to be responsible for deliver information to my team. I find it hard to manage my time, but I was able to plan ahead and incorporated **time-management skill** to help myself be ready for my team and become an **active participant** that would encourage other to have a plan and be able to accomplish the assignment in a timely manner. The skills that we have learn are important for real world **engineers**' scenarios as most project must have deadlines and most of the times you will be working hand by hand with a partner of a **customer."**

Theme 3: improving perceived learning outcomes

Students found the new curriculum to help them understand the big picture of photogrammetry. They reported on how the incorporation of new ideas will help them in the future. They also mentioned that it allowed them to look at photogrammetry from a different perspective. Examples of students' responses include:

(1) "In the new curriculum students can understand how **opportunities** can develop by the **discovery** of a small **idea** and the help of new developments as part of a process."

(2) "In the new curriculum we were able to learn how the **idea** of **bio-design** was incorporated to new designs in Drones."

(3) "The new curriculum allows for more **visually readable mapping** product that can easily relay information to the average consumer or client."

(4) "This new curriculum is effectively preparing students to **integrate the Arts** into the traditional STEM mindsets, and by doing so is preparing students to **effectively operate** in the professional world."

(5) "students are constantly given the chance to **observe** and **evaluate** in any instant that they take on, as this does include an area in and out of a school and work environment."

Theme 4: increasing interest to pursue careers in surveying

Participants acknowledged having an increased interest in pursuing surveying as a career and also expressed interest in learning more about the field.

(1) "By encouraging students to seek new methods to increase efficiency, maneuverability, durability, effective range, and data collection methods the new curriculum is helping students to **pursue** the future of drone design within the **surveying profession** and beyond."

(2) "The investigation into the past and how drones work and were developed piqued my **interest.** I hope to **have my own surveying firm in the future** so this assignment has started my way of thinking in order to be successful and thinking of different aspects of the job."

(3) "After doing this assignment I have realized that from everything I learned in college to my personal backgrounds have **all inspired** me to become a **survey engineer**."

(4) "Learning about the history of drones and where the designs came from was enriching for this class. I am very much looking forward to learning more about drones and **work in the surveying field** due to this initial research I conducted."

Theme 5: encouraging learner engagement

Students reported on the importance of the interdisciplinary learning experience, stating that it helped them understand surveying more profoundly, discover new skills, and enhance engagement. Examples of students' responses include:

(1) "I am very confident to say that because of the interdisciplinary learning experience I have the abilities **to engage** in the newly developed curriculum and successfully take with me the best possible outcome."

(2) "This interdisciplinary learning experience affected my ability **to engage** with the newly developed curriculum in many ways."

(3) "I found this approach very different and interesting and involving quite a bit of jargon. I have studied engineering and found this approach new and I can see it facilitates the **engagement** of many different interests. It **does engage** a wide variety of knowledge and this requires lots of jargon which will mostly probably be new to most students."

Theme 6: improving awareness of the role art plays in map making

Students learned in this assignment that part of the final deliverables from most surveying and engineering projects is a map, a piece of art. They recognized the importance of map-making techniques and how art is vital in preparing and finalizing their maps. They appreciated that this assignment instructed them on the importance of arts in the map-making industry. Examples of students' responses include:

(1) **"Recognizing the importance of the Arts** allows for more perspectives to be considered when approaching a STEM project."

(2) "Overall, the I found that interdisciplinary learning helped me to better understand **the importance of the Arts** in the new STEAM based curriculum, how important having an artistic eye can be when creating photogrammetry products."

(3) "The most artistic subject in my opinion as we were exploring this assignment is the **art of map making** or cartography. Utilizing numerous techniques to better achieve making the best map for their purpose."

(4) "**Learning the arts** behind it also was very **beneficial**, to be introduced on how the drone is able to capture everything with the science and art all being combined to make photogrammetry possible."

Discussion

After analyzing the data, it was found that most of the students benefitted from this newly developed curriculum and recognized its value in terms of career preparedness. For the first theme, students agreed that drones have strongly modernized the surveying and engineering professions. They recognized the value and efficiency of drones in collecting high-quality and reliable data for different projects and applications. There was an agreement that with further development in drone technologies, surveyors and engineers would benefit more from drones. One student reported about the limitations of drones: "*Drones have continued to improve as engineers have encountered limitations and have been researching methods of rectifying those limitations, and it turns out that nature has the answers*." For the second theme, results showed that most students learned communication, management, and teamwork skills. They acknowledged they had opportunities to learn new presenting tools and technologies and recognized the value of learning these skills and being job-ready. Students reported that this curriculum changed their perspective on how photogrammetry and surveying do not exist in a silo. They realized the connections between surveying and other disciplines and how they needed to understand the foundational sciences and arts on which surveying and photogrammetry are built. For the fourth theme, students acknowledged the importance of this interdisciplinary experience and the interdisciplinary nature of photogrammetry and surveying in general. For the fifth theme, students recognized the value of art and its basics of map-making. They recognized that as professional engineers and surveyors, their final deliverable is an artistic product that needs to follow scientific and engineering principles and artistic principles.

As this EM, STEAM, and bio-inspired approach to teaching photogrammetry was offered for the first time, the instructor found some important improvement areas to implement in the future. First, the schedule had to be changed at the beginning of the semester as students did not follow the deadline for step one. Second, the intervention should be implemented later in the semester after students learn more about photogrammetry; however, the history part helped them learn more about the topic. Third, providing examples to students is essential to understand what they are expected to deliver. Fortunately, one student volunteered to have the responses shared with others. This shared information helped all students know what they were expected to submit. Fourth, a hands-on activity that helps students better understand the importance of arts in map making.

The participants also reported a few challenges. First, having students finish the coursework in about a month was challenging. Another challenge was grouping the students in teams as they are distance learners and do not meet face-to-face. It was difficult for some students to follow the requirements for the deliverables at the beginning. However, the instructor resolved this issue through guidance and specific feedback. Based on the findings and overall student feedback, there is potential for this newly developed curriculum to be

implemented in future course offerings not just within geomatics engineering but also in other engineering disciplines.

Conclusion

In response to the research question, "What are the lessons learned from implementing an Entrepreneurial Mindset, Bio-inspired design, and STEAM-infused curriculum into a photogrammetry course?" this study implemented a new approach to teaching photogrammetry at a Hispanic-serving institution to address the lack of diversity in the geomatics field. The study's findings demonstrate the benefits of incorporating bio-inspired design, STEAM, and entrepreneurial mindset in engineering curricula. Our approach differs from other studies because it can be applied at any course or academic level, needs minimal effort and budget, and directly gathers student feedback. It also boosts students' professional competencies, including communication and time management, and it inspires students to create innovative technical solutions by learning from nature and developing social, emotional, and interpersonal skills. We analyzed three photovoice-reflection prompts and three open-ended reflection questions. Three photovoice-reflection prompts were about how the coursework helped students appreciate the Entrepreneurial Mindset, STEAM, and bio-inspired design, and three open-ended reflection questions were about students' experience participating in this assignment and the lessons learned. We found that students acknowledged the value of learning new technologies, the gain in their professional skills by participating in this assignment, the advantage of understanding photogrammetry as a mapping tool, the benefit of this assignment in increasing their interest in the surveying profession, the significance of the interdisciplinary learning, and the importance of arts in designing maps and other surveying deliverables. According to Bosman and Shirey (2022), incorporating bio-inspired design, STEAM, and entrepreneurial mindset in engineering curricula has multiple benefits. Fostering entrepreneurial mindsets inspires students to excel, appreciate, and innovate in engineering design and practice. Moreover, the bio-inspired design exploits opportunities so students can understand the similarities between nature- and human-centered design and their problem-solving capabilities. In addition, adding STEAM, particularly the art component, improves their interdisciplinary engineering solutions skills.

Implications for practitioners

An EM, bio-inspired, STEAM-infused curriculum should be extended to other courses and disciplines that promote interdisciplinary learning, broaden participation and engagement amongst underrepresented groups, and create a more inclusive classroom. Special consideration should be given while integrating this approach in your classrooms/courses, such as flexibility in deadlines, exposing students to similar interventions in other courses, inclusion of hands-on activities for knowledge application and skill enhancement, and offering networking opportunities with professors within the institution or professionals in the industry. Based on the classroom's needs and the course's learning objectives, this approach can be replicated and applied across a wide variety of settings.

Limitations and future research

While the study offers some noteworthy contributions, there were a few limitations. First, this study was limited to students mainly pursuing surveying in photogrammetry at our Hispanic-serving institution. Future research should implement a similar project in future classes, other disciplines, at other universities, and with different instructors. Second, we should also consider studying other diversity factors such as economic status, sexual

orientation, and gender identity. Third, the coursework was introduced in a distance-learning environment, and future research should also consider hybrid and face-to-face learning environments. Fourth, we only used a qualitative data analysis approach [thematic analysis]. Future research should consider using other qualitative or mixed methods approaches (e.g. statistical/quantitative analysis).

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