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Development of a Manufacturing Assessment Survey to Promote Entrepreneurial Mindset in Engineering

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Abstract

Most manufacturing content taught in the engineering classroom is presented passively using pictures, videos, and numerical methods. Few universities utilize an active lab component for manufacturing courses leaving students with visual media for learning a traditionally hands-on process. To address this gap, we present an entrepreneurially minded manufacturing assessment survey assignment where students research and select a product that is relevant to the material covered in class. The assignment is a formal manufacturing assessment survey that allows students to investigate "real-world" components to explore how they were manufactured with justification as to why the product was made using this specific process. Students produced a manufacturing assessment survey for each of the major manufacturing topics learned in the class. At completion, students completed a photovoice reflection for one of the assignments (manufacturing lesson on corrosion and erosion) to reflect on the manufacturing survey. In this paper, we present the survey assignment and photovoice reflection on corrosion and erosion, specifically, as it is traditionally considered a negative surface phenomenon. Thematic analysis of the photovoice reflections show that students are motivated to explore mechanisms for increasing system value and identifying opportunities. Ultimately, findings suggest that the use of hands-on surveying assignments to compliment the traditional teaching methods used in manufacturing classrooms can promote an entrepreneurial mindset when studying manufacturing content.

1. Introduction

Industry 4.0, the fourth industrial revolution and the underlying digital transformation such as cyber-physical capabilities, communication technologies, and the internet of things is advancing exponentially [1], [2], which has influenced how design and production are performed worldwide - from the consumers to the manufacturer. The President's Council of Advisors on Science and Technology has acknowledged the global competitiveness in manufacturing-related fields as recently as January 2021 [3]. Manufacturing in the United States supports 12.2 million employment [4] and generates 11% of GDP [5] , making it the third largest contributor to GDP after government and real estate. Its economic significance cannot be overstated. The proper implementation of Industry 4.0 might rebuild the manufacturing that the United States has lost over the past decades [6] and place the United States as the world's manufacturing leader.

The revival of manufacturing in the United States begins with educating the next generation of engineers on its fundamentals in the classroom. Although manufacturing remains a significant part of many mechanical engineering curricula at universities in the United States, these courses are often taught in a way that is similar to other technical courses, with most of the education taking place within the classroom.

As manufacturing deals with the art of making, there is an opportunity for students to understand value and innovation through manufacturing courses. With the lack of real-world experience, there is a missed opportunity for students to achieve Entrepreneurially Minded Learning (EML). EML does not revolve around monetary profit-making ventures, as indicated by [10,11]. Instead, it emphasizes the unique problem-solving perspectives that entrepreneurs adopt [7], along with the cognitive abilities that enable them to address those problems in an entrepreneurial way [8]. These aspects of EML contribute to fostering an entrepreneurial mindset. EML teaches students how to develop economic and social value and prepares students to contribute to existing engineering enterprises in a manner that promotes value creation [9].

Depending on the course being presented and the objectives of the lecturer, manufacturing classes are frequently taught in a variety of ways. In general, lectures, hands-on laboratory or workshop sessions, and project-based work may all be included in manufacturing curricula. When teaching manufacturing courses and lectures are frequently utilized to provide students with an overview of the fundamental principles in the field. A range of different technologies can be used to deliver a lecture such as online or in a classroom setting. Additionally, manufacturing courses could also include hands-on laboratory or workshop sessions where students get to use actual manufacturing tools and equipment. These classes are made to give students real-world experience with procedures and methods employed in the field.

Traditionally, Mechanical and Industrial Engineering were the two STEM majors that included manufacturing courses [10]. Many of these courses used to include a lab to compliment the course to provide students the opportunity to simulate the manufacturing process (casting, machining, bending, etc.) learned in class. However, there is a recent decline in the number of engineering technology programs. This has resulted in a situation whereby most manufacturing courses are taught using the same methods as other engineering courses (lecture heavy) and lack the real-world learning experience necessary for students to understand and immerse themselves in the content.

1.1. Study Overview

This paper presents a curricular assignment for use within manufacturing courses that can compliment the course in the absence of a formal lab component. The assignment – a manufacturing assessment survey used for students to understand various manufacturing processes and phenomenon through personal exploration and inquiry – is assigned to students after presenting each manufacturing process in class. In this study, we explored student reflection of the assignment to determine if this assignment led to greater content engagement and enrichment. Specifically, we address the following research questions:

RQ1: What indicators of Entrepreneurially Minded Learning were observed when utilizing the Manufacturing Survey?
RQ2: What differences did students observe when utilizing the Manufacturing Survey?

To analyze the reflection, we employ a qualitative data analysis method – Topic Modelling – to extract student thematic responses. Topic modeling is a method of identifying the main topics that are discussed in a collection of documents. It is a type of unsupervised machine learning, which means that it does not require the use of pre-labeled data. Instead, the algorithm is able to analyze the text in the documents and identify common themes or topics based on the words and phrases that are used.

To perform topic modeling, the algorithm first analyzes the text in the documents to identify the most frequently occurring words and phrases. It then groups these words and phrases into topics based on their co-occurrence in the text. For example, if a collection of documents contained a lot of words related to politics, the algorithm might identify a "politics" topic. The specific topic modelling approach utilized is Latent Dirichlet Allocation (LDA) [11]. LDA uses Bayesian Inferencing to identify topics that emerge from a set of corpus, of which each possesses a set of words.

2. Background

One of the primary goals of engineers and innovators is to generate new technology in addressing societal needs. This is a challenging task as societal needs are often volatile [12], or ill-defined. To address such challenges, an entrepreneurial mindset is required. Beyond the traditional innovation and engineering efforts, those with an entrepreneurial mindset seek to find opportunities of unmet needs in the market that could yield a successful implementation and/or growth in new or existing technologies. Whereas engineers are typically programmed to develop new solutions, entrepreneurially minded engineers are educated in identifying the most appropriate solution to these newly uncovered needs, regardless of whether they are new or existing solutions that may be integrated or augmented to satisfy the market need. While there are multiple definitions for entrepreneurs, this paper posits the definition that states "Entrepreneurs, in the purest sense, are those who identify a need—any need—and fill it. It's a primordial urge, independent of product, service, industry or market" [13]. Ultimately, the success of an entrepreneurial engineer depends on their ability to validate, attract, and acquire customers who seek to extract value from their innovation, which increasing is developed from existing technology platforms rather than brand new, theoretical, or esoteric developments.

The mindset of utilizing existing technologies, variations thereof, and/or finding new application-opportunities is commonly understood to embody the Entrepreneurial Mindset [14]. This mindset is critical in ensuring resources spent on innovation or engineering efforts appropriately find new means for utilizing the existing technology beyond its initial scope. Multiple engineering foundations, such as the Kern Entrepreneurial Engineering Network (KEEN) have focused on the importance of the entrepreneurial mindset on the future of engineering [15].

In this study, we specifically explore Entrepreneurial Mindset in Manufacturing courses. Manufacturing has always played a significant role in engineering education. Manufacturing was one of the earliest types of engineering – as the focus was placed heavily on fabrication and making. While formal manufacturing education has decreased over the years, there are still elements of this in educational institutes today. For example, the maker movement has gained significant traction and resulted in the development and build of various facilities around institutes of higher education throughout the United States [16]. Given the importance of manufacturing in engineering curriculum, there is an opportunity to explore if the manner in which manufacturing is taught and if the pedagogical methods employed impact entrepreneurial mindset.

2.1. Manufacturing Education for Engineers

Manufacturing education is a type of education that focuses on teaching individuals the skills and knowledge they need to work in the manufacturing industry. This may include technical skills such as operating machinery, as well as a broader understanding of the manufacturing process and how different parts of a manufacturing facility work together [17]. Manufacturing education can be obtained through a variety of programs, including vocational schools, community colleges, and four-year universities. The goal of manufacturing education is to prepare individuals for careers in this important industry, which plays a vital role in the economy.

Manufacturing coursework is important within engineering programs because it provides students with the practical skills and knowledge they need to design and produce high-quality products. Engineers who have a strong understanding of manufacturing principles and processes are better able to design products that are feasible to produce, cost-effective, and efficient. In addition, manufacturing coursework can help engineers develop an understanding of the various factors that go into the production of a product, such as materials selection, production processes, and quality control. This knowledge is essential for engineers who want to create products that meet the needs of their clients and the market.

Manufacturing traditionally starts with a set of requirements [18], [19] a system must fulfill. One of the main challenges with teaching manufacturing courses is staying up-to-date with the latest technologies and processes in the industry. Manufacturing is a rapidly changing field, and it can be difficult for educators to keep pace with the latest developments. This can make it challenging for them to provide students with the most current and relevant information. Another challenge is finding appropriate facilities and equipment for students to use in their coursework. Manufacturing courses often require students to have hands-on experience with a variety of tools and machinery, and it can be difficult for schools to provide access to the necessary equipment.

2.2. Active Learning

The use of hands-on learning has long been recognized as important in engineering fields, particularly manufacturing [20]. One such way to achieve this is through active learning to give the students authority over what they are learning. The definition of active learning and how it varies from conventional engineering education are still topics of confusion for many faculty members. Engineering professors often struggle to distinguish between the many types of active learning, and most of them are not inclined to search educational literature for clarification, which furthers the confusion [21]. Active learning is a general term used to define any type of pedagogical instruction that provides students with an active role in the learning process which is the core element of these methods. Students must participate in valuable learning activities and reflect on their actions in order to engage in active learning [21]. While this broad definition can encompass many classroom activities, there exists more restrictive definitions such as that in [22] which suggests active learning is comprised of short activities that are assigned to students with some parts led by the instructor. There are others that suggest active learning requires cooperation between students in the classroom [23] as the interpersonal element plays a role [24].

Active learning is a teaching method in which students are actively engaged in their own learning, rather than passively receiving information from a teacher or instructor. In active learning, students are encouraged to participate in their own education by asking questions, conducting research, and working on projects and assignments that help them apply what they have learned. Active learning is different from many teaching methods, in which the teacher is the primary source of information and students are expected to passively absorb that information. In active learning, the teacher's role is more facilitative, helping students to explore and discover information on their own. There are many benefits to active learning, including increased engagement and motivation, improved critical thinking and problem-solving skills, and better retention of information. Active learning can be applied to a variety of educational settings, from primary schools to universities, and can be used in a variety of subject areas. During in-person classes, active learning strategies have been used to motivate students to comprehend engineering concepts. However, the worldwide COVID-19 pandemic caused engineering instructors to move their classes to an electronic platform, which had an effect on instructional efforts and the implementation of active learning activities [25].

Ultimately, we consider the proposed manufacturing assessment survey a form of active learning as it differs from other forms of instruction since students must know think about what they are doing to enable learning. This notion is supported by prior research specifically in manufacturing education environments. For instance, prior research on active learning in manufacturing environments has used psychomotor learning to engage manufacturing students, given the cost of manufacturing instructional laboratories [26]. We consider the proposed manufacturing assessment survey as a form of active learning as students are implored to consider various types of products – on their own – that align with the content taught in the class. This is not to suggest that active learning is designed to replace hands on labs, but it can be used to compliment lecture heavy courses.

The author posits that a course focused on manufacturing has the potential capacity to foster EML. This is attributed to manufacturing's inherent suitability to the fundamental aspects of EML: curiosity, connections, and creating value. Manufacturing facilitates the realization of ideas into tangible products, an experience that is not commonly observed in other engineering courses, especially those that are primarily grounded in theory and scientific principles. As such, this course presents an occasion to investigate how the suggested modifications can encourage the development of EML.

3. Pedagogical and Research Methods

In this study, we developed a manufacturing assessment survey that is designed to promote student thinking about how a particular product was designed. The purpose of the survey was to develop a connection between what students learned in the course and their observations when reviewing a candidate product made using the process learned in class.

The manufacturing assessment survey was administered to students a total of eight times throughout the semester, covering various manufacturing topics. In the study presented in this paper, we use one of the weekly manufacturing surveys to serve as an exemplar for data collection and student reflections. We do this for two purposes: (1) it is not pragmatic to collect reflection data from students after each manufacturing assessment survey assignment as there were eight throughout the semester and (2) we selected the manufacturing assessment survey that covered a topic that does not have a strong correlation to entrepreneurial mindset in manufacturing – corrosion and erosion. If students can realize entrepreneurial mindset in this topic, we were confident they could realize it in any of the other manufacturing lessons covered in the course.

3.1. Subjects – Senior Mechanical Engineering Students

The class where this study was administered is a senior level manufacturing course. Fifteen students participated in both the manufacturing assessment survey and photovoice reflection. The 15 students were comprised of mechanical engineering seniors where 13 were male and two were female.

3.2. Setting – Senior Level Manufacturing Elective

The course setting was an elective manufacturing course for senior level students. The course has three primary objectives: (1) Model and analyze a representative set of fundamental manufacturing processes in use today. Derive expressions for expected process and product characteristics (e.g., forging forces, expected tolerances), (2) Prescribe a manufacturing process or combination of processes for producing a given part based on metrics of success such as specific cost and output rate and subject to design constraints such as tolerance, quality and application-specific need, and (3) Identify manufacturing processes used to make a given part. Suggest improvements to existing part and process designs based on economy and an understanding of the prescribed manufacturing process. The manufacturing survey is given to students as part of a homework assignment they are required to complete. Each manufacturing survey assignment is based on the course content covered during the previous week in class.

3.3. Intervention – Manufacturing assessment survey

Every week, students are required to complete a manufacturing assessment survey that reflects their understanding of the concepts covered in class during that week. To do this, they must explore any product they come across and determine whether it could have been manufactured using the process learned in class that week. The survey includes an explanation of the manufacturing process used for the product (such as die casting), an identification of other possible manufacturing processes that could have been used (e.g., forging, rolling), and an explanation of the parameters that dictate which process should be used. Students are encouraged to select products they are familiar with and interested in, as this provides an opportunity to learn something new about a product they are passionate about [27]. They can also choose to analyze single parts or assemblies, which requires them to consider assembly and disassembly [28]. This active learning approach allows students to apply what they learned in class to analyze and survey different components, enhancing their learning experience.

As part of the assignment, students are also required to identify a product that was manufactured using a biomimicry-inspired process. This allows them to develop formal manufacturing knowledge and skills related to their hobbies or interests, while cultivating an entrepreneurial mindset by encouraging them to consider different manufacturing processes that could improve the value of a product, whether economically or socially [29], [30]. The assignment also incorporates elements of aesthetics, encouraging students to think beyond product functionality and consider design aspects. This combination of biomimicry, entrepreneurial mindset, and art adds a unique perspective to traditional manufacturing processes education. For example, if students were taught about biomachining, they would be expected to find products that exhibit properties similar to biomachining, such as erosion, corrosion, and pitting. The manufacturing assessment survey asks students to:

- Summarize the content learned in classroom that week
- Identify a product that they believe was made using that process (and attach a picture of the product)
- Provide physical justification/evidence for why the product was made in the manner it was made
- Describe and justify other processes that could be used to make the same product

An example manufacturing assessment survey completed is shown in Fig. 1. The survey was assigned weekly and based on the content recently covered in class. Content does not have to be new manufacturing processes, but can be content that is related to manufacturing.

Manufacturing Topic: Surface Roughness

Item Selected: Skateboard

1) **Explain how the item was manufactured?**
   The process of making a skateboard is quite simple once all the components that make the skateboard are available. The main component of the skateboard is the board, and this is usually made from wood or plastic if it is wood, it can be machined or done manually, it it's made from plastic just like the wheels are a much more complex process takes place. The process starts by having molds made from steel, after the molds are ready, liquid polyurethane is poured into the molds and then transferred into an oven. Finally, the wheels or board are made and are ready to use. Just in this one item we can see multiple different surface roughness and they all play an important role for the proper functioning of the item. There are a variety of options when it comes to the wheels. Size, roughness, and hardness can determine the well-functioning of the skateboard in different terrains. Boards are also added a layer of "sanding paper" that provides much higher surface roughness and therefore a higher coefficient of friction to give the skaters a better grip when riding the skate
2) **What leads you to believe it was manufactured in this manner?**
   When growing up I was a big fan of skating, I got very passionate about skating. Coming from a less developed country and not having the resources to buy a branded skate forced me to make one myself. At a very young age I also expressed interest in engineering or at least on how things were made. Luckily, I was able to make the skate and all I had left to buy was the wheels. Since buying was never an option, I started asking professors how wheels were made and if there was a way of making the wheels myself. I had wheels made of metal and a set made of ceramic these seemed to work but did not provide the performance that the "plastic" ones provided. It was not until Christmas next year that I got a set of "plastic" wheels
3) **How else could it have been manufactured?**
   As mentioned before, wheels could have been made from metal, my guess would be that casting would the best option for wheels out of metal. For the board, it could have been done manually just by getting a piece of wood and start cutting excess material to give the desired shape. The wood could have also been machined or lastly it could have been done by plastic injection molding.
4) **Attach a Picture of the item:**

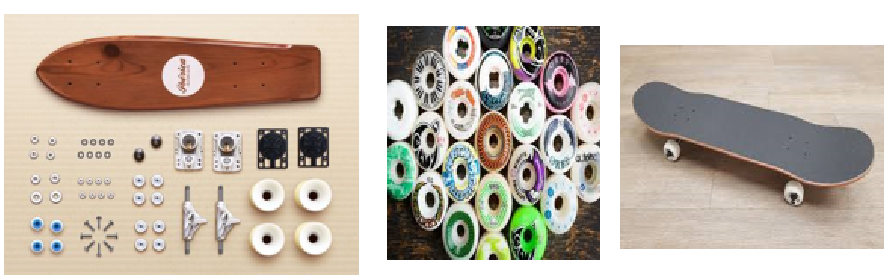

Fig. 1: Example manufacturing assessment survey Completed by Students for demonstrating surface roughness on a skateboard

While motivation is not a major component of this paper, it is important to note the impact such an assignment can have on student motivation. Prior research has indicated the importance student motivation has on student performance in a course [31]. Further, we have witnessed how mechanical engineering students in particular possess different types of student motivation [32], particularly toward real-world applications [33]. An assignment as the one proposed in this paper could increase student motivation toward the content, which in turn can improve student performance. While this specific phenomenon was not investigated in this context, we hypothesize that it will have a positive impact on student learning

3.4. Data Collection – Metacognitive Photovoice Reflection

For one of the assignments – where we specifically selected corrosion and erosion topics for that week – students were required to complete a photovoice reflection [34]. The manufacturing assessment survey was analyzed using the photovoice reflection to determine student reflection on the assignment and its ability to promote entrepreneurial mindset, recognition of STEAM in the assignment, and the role of bio-inspired design. Further, students will complete open ended questions related to the interdisciplinary approach to the assignment, a debrief, and the assignments connection to real world applications. In this study, we will only consider the questions related to Entrepreneurial mindset and the open ended questions where they may elaborate on their thoughts. We use the questions to address the research questions as the first question relates specifically to EML and the open-ended questions allowed us to determine what gains the students experienced through the manufacturing survey. Specifically, the survey items we will present here are:

1. Entrepreneurial mindset – The goal of this question is to determine how this type of assignment prompted students to consider the elements of entrepreneurship in their manufacturing survey. Specifically, does performing a manufacturing assessment survey over standard homework assignment allow students to make entrepreneurial mindset gains that they otherwise would have missed.
   Question: The entrepreneurial mindset is defined as "the inclination to discover, evaluate, and exploit opportunities." Explain how participating in the newly developed curriculum incorporated the entrepreneurial mindset, and lessons learned relevant to the entrepreneurial mindset.
2. General Debrief – Inquires students on what went well and didn't go well with the manufacturing assessment survey.
   Question: What went well? What didn't go so well? What will you do differently next time?
3. Real World Connection – Determines if students can see real world connection and value of the manufacturing assessment survey.
   Question: What skills did you learn? Please consider both professional skills (e.g., communication, collaboration, etc…) and context specific skills (e.g., topic area). Why are these skills important for engineers in the real world?

3.5. Data Analysis - Latent Dirichlet Allocation

LDA treats a given corpus compiled of all student interview transcriptions as a collection of documents (M) where each document consists of N words $\boldsymbol{w} = (w_1, w_2, \ldots, w_N)$. Assuming each corpus contains a mix of interpretable topics, LDA constitutes a hierarchical model to approximate the topics-word and document-topic distributions [11]. The important function that must be solved is the posterior given by the equation (1)

$$p(\theta, z \mid w, \alpha, \beta) = \frac{p(\theta, z, w \mid \alpha, \beta)}{p(w \mid \alpha, \beta)} \quad (1)$$

where

α is the Dirichlet prior for the distribution of topics

β is a topic-word matrix representing the probability of a word for each topic

θ follows a multinomial distribution of topics representing the probability of a topic in a document. To solve for $p(\boldsymbol{w} \mid \alpha, \beta)$, we can identify a marginal distribution for the document as shown in equation (2)

$$p(\boldsymbol{w} \mid \alpha, \beta) = \int p(\theta \mid \alpha) \left(\prod_{n=1}^{N} \sum_{z_n} p(z_n \mid \theta) p(w_n \mid z_n, \beta) \right) d\theta \quad (2)$$

Model hyper-parameters α and β are designed to be estimated (which can be accomplished through various estimation methods). Collapsed Gibbs sampling, a common-use technique, was performed to approximate posterior distribution for LDA. This study will only present the responses for the questions pertaining to entrepreneurial mindset and the open ended questions where students can provide their input on the experience. As the focus of this paper is the entrepreneurial gains from the manufacturing assessment survey, we scoped the analysis accordingly.

4. Results

4.1. Entrepreneurial Mindset

Fig. **2** provides a visual of the topic modelling study related to entrepreneurial mindset (Question 1 of the photovoice reflection). This figure represents the topics that emerged when modelling the topics in an eigenspace. The x-axis and y-axis are Principle Components 1 (PC1) and Principle Component 2 (PC2). The results determined four topics that emerged from the topic modelling. It is difficult to assess what the topics themselves are and a review of the words associated with the topics nondeterministic. As a result, the authors took the approach of analyzing the principle components instead to determine where those topics lie in the eigenspace. Based on an observation of the topics, the principles components seem to suggest the themes lie on the dimensions of Manufacturing Processes and Knowledge.

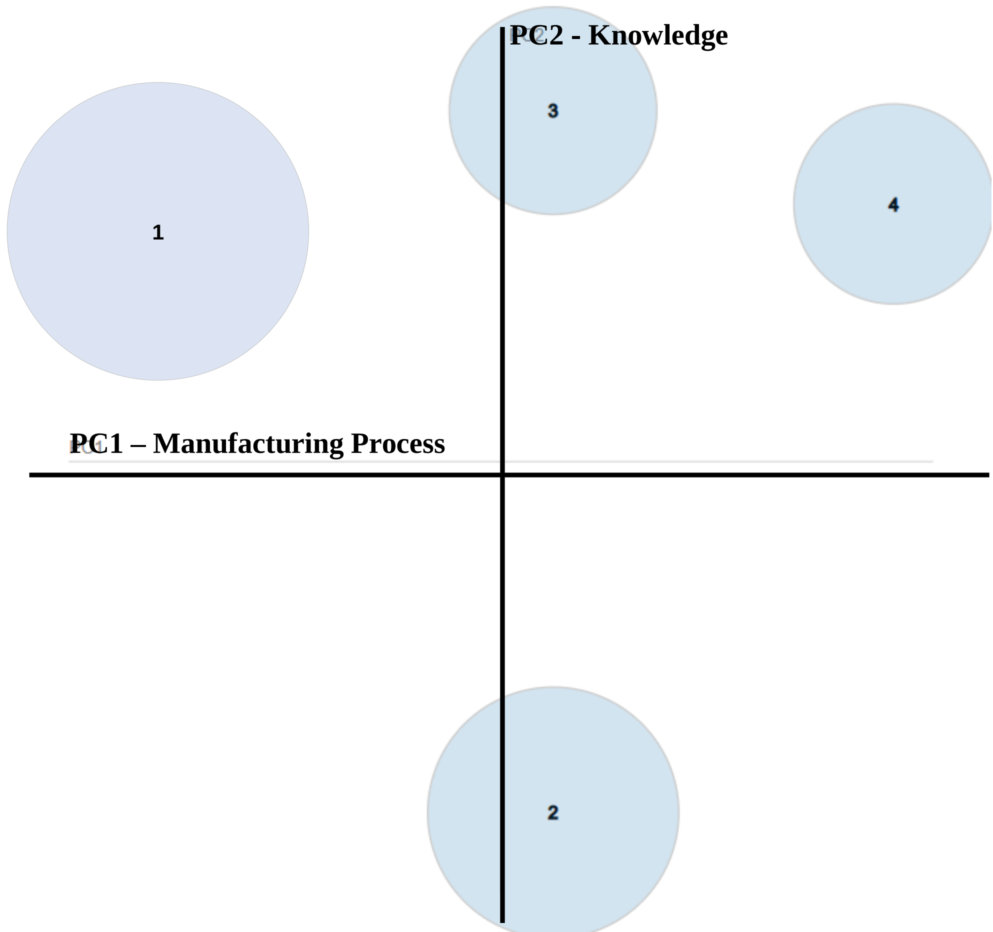

Fig. 2: Topic Model Results of Questions Surrounding Entrepreneurial Mindset

The specific words captured within each of the topics identified for the Entrepreneurial Mindset question is shown in Fig. **3**. Topic 1 and Topic 4, which appear to lie on diametrically opposing sides of the same principal component highlight the processing and material. On the other axis, Topic 2 and Topic 3 also lie diametrically on it. Topic 2 and Topic 3 relate to the making and innovation required to make, respectively. The length of the line suggest the frequency of the terms in each of the topic. Fig. **3** illustrates a rank order of the frequency of which a word appears in the topic. The bar that is illustrated alongside each word represents the ratio of how many words appear in that respective topic compared to the total number of word appearances in a document. A full bar would suggest that all the instances of that word's appearance in the document occurred in that respective topic.

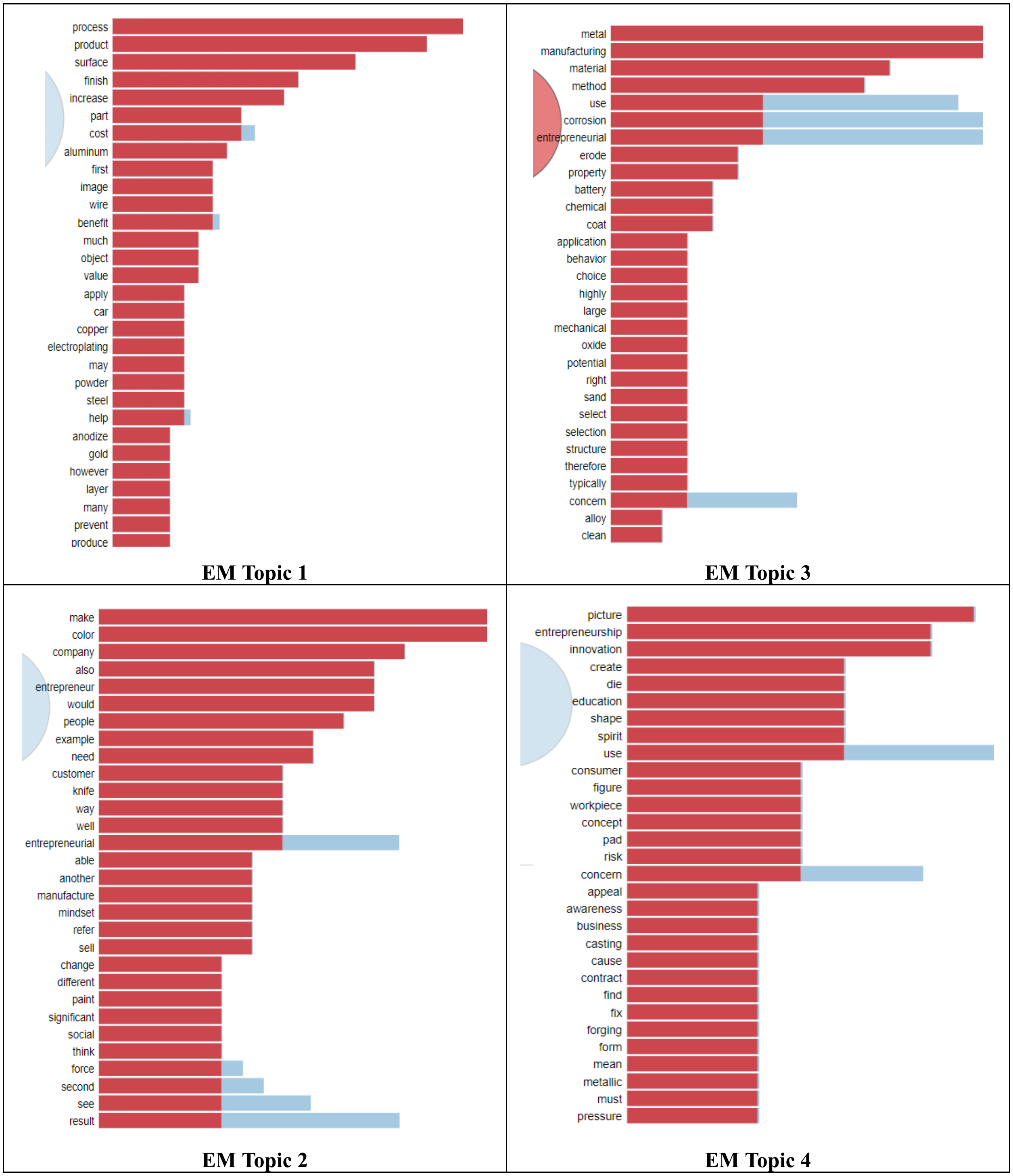

Fig. 3: Words Associated with Each Topic Generated from Questions Related to Entrepreneurial Mindset

4.2. Open Ended Responses

Student's open ended question discussion revealed information related to their overall thoughts of the assignment, particularly as it compares to standard homework assignments.

Students highlighted the importance of gaining skills in manufacturing and the knowledge necessary to accomplish various manufacturing processes.

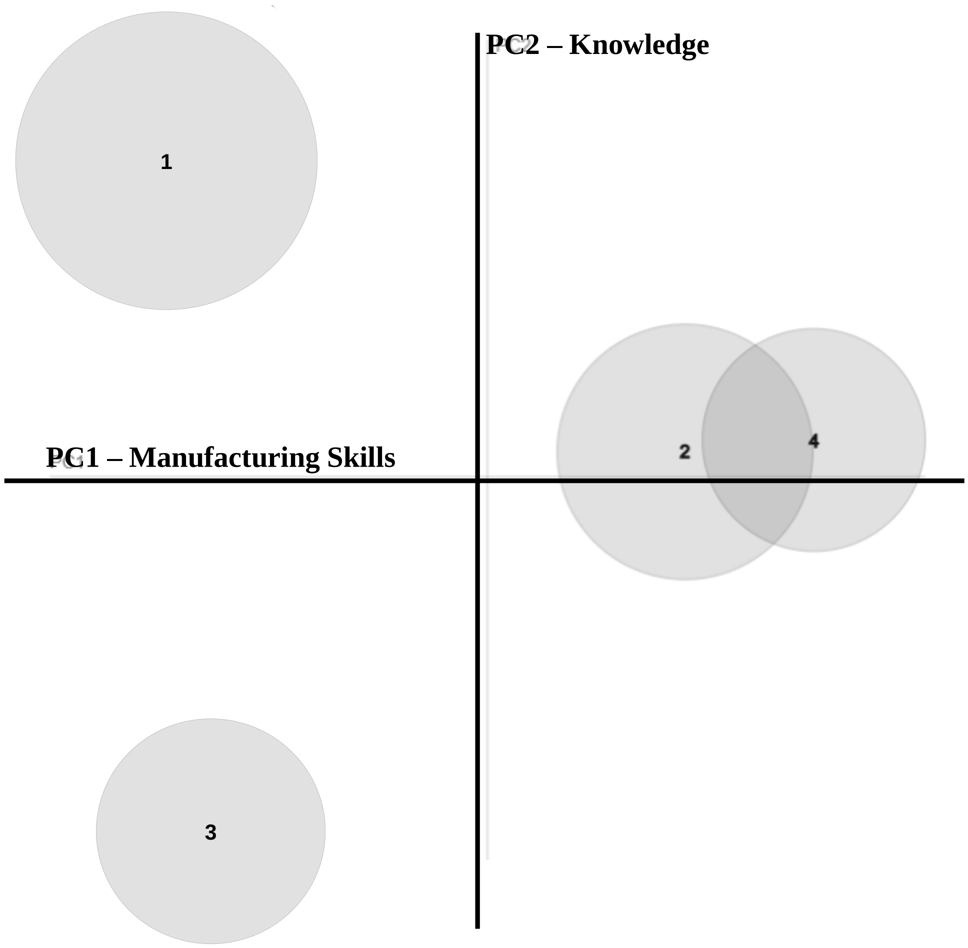

Fig. 4: Topic Model Results of Open-Ended Reflection Questions

The words that were selected for reach of the topics is shown in Fig. **5**. When observed against Fig. **4**, Topic 1 and Topic 3 lie diametrically opposing in one axis while similar in another. Conversely, Topic 2 and Topic 3 seems to have significant overlap. Topics 1 seems to focus on the gained knowledge that the manufacturing assessment survey stimulates in students. Topic 3 highlights elements of the part and process the students were exploring. Through various approaches (such as performing research) while Topic 3 highlights elements of the particular part and process necessary to make it. Topic 2 and Topic 4, which possessed significant overlap highlighted skills related to thinking and understanding how it works – even going as far as mentioning curriculum.

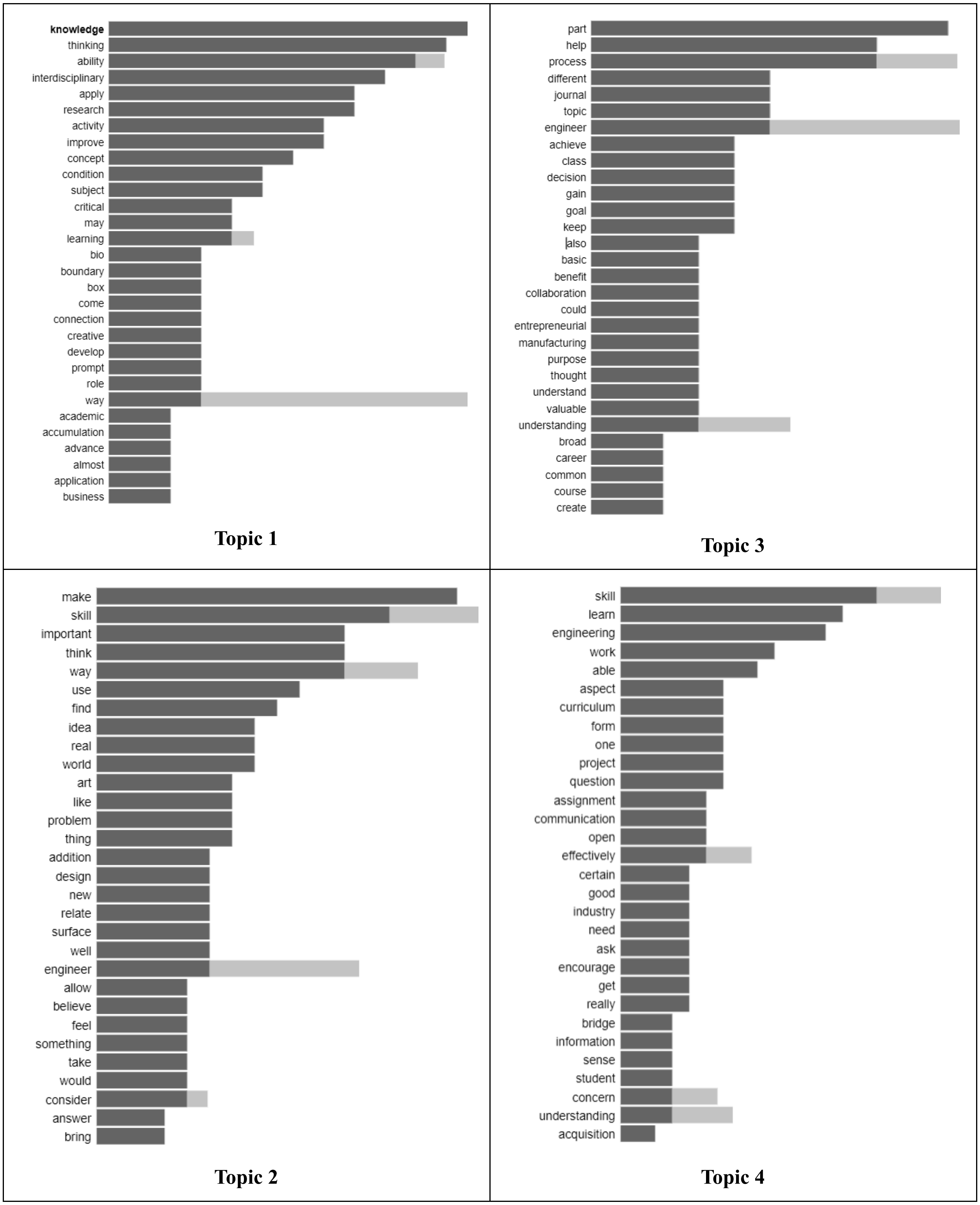

Fig. 5: Words Associated with Each Topic Generated from Open Ended Questions

5. Discussion

The results of the topic modelling for the Metacognitive Photovoice Reflection questions related to entrepreneurial mindset suggest that students considered the aspects of the manufacturing process and knowledge necessary. Within knowledge, students highlight the importance of entrepreneurial mindset necessary to promote creativity and innovation. Consider the student responses below to highlight this observation:

> *"However, the journal assignments force students to understand why these processes are done, which includes an entrepreneurial component. It begs questions like what is the purpose of putting parts through these extra processes and costs and what is the financial/competitive gain or value."*

> *"…we should explore the inherent elements of innovation and entrepreneurship education in professional education and deepen the reform of professional education and teaching."*

The results of the topic modelling for the open ended questions suggest that students valued the nontraditional approach of the manufacturing assessment survey – referencing the knowledge and skills gained when using this approach. Consider the student responses below to highlight this observation:

> *"I have gained valuable knowledge and skills that will directly apply to the career of a process engineer which I hope to being upon graduating."*

> *"The broad knowledge this course is teaching me will likely help me have a basic understanding of some of the processes in a plant, allowing me to gain a deeper understanding more quickly."*

Alongside the educational gains of using a manufacturing assessment survey over standard manufacturing homework, we see gains in student entrepreneurial mindset, particularly in the areas of curiosity, connections, and creating value. In creating this manufacturing survey, this was very intentful. For instance, consider the assignment on surface conditions (corrosion, erosion, etc.) that is typically considered negative:

5.1. Curiosity

Corrosion and Erosion are typically viewed as negative phenomenon - something you don't want as an engineer. However, this assignment implores students to think about these surface phenomenon in a way they did not consider before. Students consider how it could be used for arts, entrepreneurial mindset, and how this to help us understand bio machining.

Most interpretations of corrosion and erosion are negative. However, a contrarian view would suggest that there may be positive reasons why someone may want to have such surface phenomenon. For instance, consider a scenario where a design requires a material reveal new surfaces over time. How could corrosion and erosion be used to stimulate this? Why considering a contrarian view, one could consider new, alternative ways to use an existing phenomenon.

> *"I can think about how it could have been made differently to avoid this failure and make assumptions how a new part should be made before doing further investigating."*

5.2. Connections

By thinking of different ways to use an existing phenomenon, we implore students to make connection to adjacent disciplines. For instance, consider the relationship between corrosion and biology or corrosion and arts. Students can make connections between a relatively well known phenomenon to learn more complex, new things.

> *"Interdisciplinary learning enables me to fully understand the power of synthesis, experience various connections between man, nature and society, cultivate my integration and synthesis ability, interdisciplinary thinking habit and overall thinking ability, and stimulate my creative potential."*

5.3. Creating Value

Corrosion and Erosion have traditionally been considered low or even negative value (as they cause surface degradation). However, there may be potential for value creation if students can think about this phenomenon deeply and in new ways. In doing so, we explore how phenomenon that is usually perceived negatively can be positive in some ways.

> *"Tumbling not only improves on the surface finish by way of eroding the imperfections, but it also increases the value pf the product because of its nicer/smoother finish."*

6. Conclusions and Future Work

The results of the paper suggest that students who completed the manufacturing assessment survey had considerations for entrepreneurial mindset. Topic modelling analysis using LDA revealed that when considering entrepreneurial mindset, students considered axis of Manufacturing Process and Knowledge. The manufacturing process axis included student consideration of both picturing what the component would look like and how it would be made. The second axis, which considered knowledge, students thought about the process and material required throughout the process. The open ended questions prompting students to consider the real world implications of their work found themes that lied on the axis of gaining knowledge and changing the way they think.

The themes generated from the topic modelling analysis of the manufacturing assessment survey reflection suggests that students are thinking about manufacturing knowledge and the skills necessary to manufacture a product when completing the manufacturing survey. Further, students were able to integrate elements of entrepreneurial mindset by envisioning the part and the resources required to make it. This finding aligns with the initial thrust of the assignment –

to think about how this part could have been made and other ways it could be manufactured. The themes extracted from the open ended reflection suggested that this assignment increased the knowledge gained from the course content and changed the way students think about the topic.

While the creation of the manufacturing assessment survey was preliminary, this starts a discussion on the utility of standard homework assignments. It is difficult to compare at this point because a similar analysis on students who performed traditional homework is absent from this study (though the results here suggest it is worth exploring). Naturally, future work includes a comparison of other homework assignments to that proposed in this paper. Further, there is also an opportunity to identify the types of courses that are conducive to this type of homework assignment.

7. References

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