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An Evaluation of a Healthcare-Focused Additive Manufacturing Class: Undergraduate Knowledge, Communication Skills, and Perspective-Taking

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(NSF IUSE 2337087 and 2337088)

Abstract: This project studied the effects of a class (N=25) on additive manufacturing in a point-of-care healthcare setting funded by NSF IUSE (2337087 and 2337088). This class was run simultaneously with the same curriculum and research methodology at two large public universities. Data were pooled. We focused on two main areas of growth for the engineering undergraduates enrolled in the class: i) knowledge and skills in additive manufacturing in a healthcare setting, ii) skills in communicating with other engineering undergraduates and with healthcare professionals. To determine growth over the course of the semester, we employed both objective and subjective metrics using both qualitative and quantitative methodologies developed by the team. Specifically, we measured content area knowledge through a quiz containing both multiple choice and essay responses at the beginning and end of the semester. This was a statistically significant increase (+10.12, $p<.001$). We measured formal written skills through students' responses to hypothetical email prompts at the beginning and end of the semester. We saw a statistically significant increase in their ability to take another's perspective during problem solving (+ .48, $p<.05$). We measured formal spoken skills through mock job interviews conducted at the end of the semester in which the theme of perspective-taking continued: students used many of the skills practiced during the semester to deal with hypothetical scenarios during the semester. When looked at in alignment with the results concerning students' ability to take another's perspective, this leads us to conclude that the majority of the growth in communication skills was about the ability to understand another person's goals, motivations, and behaviors in micro-level communication.

Pages, excluding Title Page and Bibliography: Five

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1. Introduction and Contextualizing Literature:

Research about teaching communication skills to undergraduate engineering students indicates: a) they are integral to later professional success [1], b) current communication skills among these undergraduates may be hampered by Covid-era lockdowns [2], and c) the ability to take another's perspective is essential and a necessary component to engage in those communication skills [3]. Thus, this project first examines whether engineering undergraduate students i) increased in knowledge and skills in additive manufacturing (AM) during the semester. Then, to address communication skills, we examine ii) what that growth is. In the class, we break communication skills into four: written formal, written informal, spoken formal, and spoken informal. This paper focuses on the formal spoken and written aspects.

One of the major obstacles when starting this project is making sure that the students are learning communication skills in a concrete, dyadic, and pragmatic way. We wanted to be sure that they are practicing those communication skills with actual professionals in another field, rather than learning about best practices in abstract or only practicing with other engineers. Thus, we chose healthcare (students learned about how to apply AM practices in a point-of-care setting) to theme and provide communication partners (medical doctors who are part of this project and their students). This created a more authentic and challenging setting for students. Additionally, healthcare is one of the fastest growing sectors of the American economy [4].

1.1 Communication Skills as Part of Professional Success

As [5] notes, communication is "multifaceted and incorporates various elements, such as oral, written, listening, visual, interdisciplinary, etc." (p. 89). Additionally, it is a required social skill that professionals must develop to engage with other varied disciplines as well as their own. Indeed, schools are responding to this need: colleges are pushing for communication skills to be implemented into engineering classes for students to learn how to communicate and sympathize with others [6]. ABET notes that engineering schools must prove that their graduates have "an ability to communicate effectively with a range of audiences…[and] an ability to function effectively on a team whose members together provide leadership" [7]. This is because of the connection with later professional success [6]. Regardless of specialty, communication is needed.

Within communication, perspective-taking is a foundational skill. To be able to effectively determine what the other wants out of an encounter, one must be able to mentally forecast with some accuracy the goals of the second [9]. It is easier to accurately predict what someone in the same profession wants because of the similarity in training and mindset, but it can become more difficult to predict what others who are trained differently want out of an encounter [10]. While the overall dataset is vast, because of these reasons, we focus this report on perspective-taking.

1.2 Study Research Questions

RQ1) What are the knowledge and skill effects of a class on additive manufacturing in healthcare on undergraduate engineering education students?

RQ2) To what extent can enrolled students improve their formal communication skills with healthcare professionals?

1.3 Intervention Details

The class provided detailed principles, theories, and applications of additive manufacturing (AM) techniques, such as extrusion-based, power-based, vat photo-polymerization, material jetting, etc. For each AM category, definitions, principles, advantages, and limitations were demonstrated. To teach communication skills, we created modules on spoken formal skills, spoken informal skills, written formal skills, and written informal skills. We spent about a class period on each, starting with a short presentation to teach the concept and then a group exercise. We followed up with brief assignments graded for completion. We are happy to share materials.

2. Methods:

To answer the study's research questions that necessitated both objective and subjective data, two methodologies were used: quantitative and qualitative, at two data points (Time 0: beginning of the semester and Time 1: end of the semester). The study has three sources of data: a) a knowledge check on point-of-care AM content containing both multiple-choice and essay questions (Time 0 and Time 1), b) hypothetical email prompt responses (Time 0 and Time 1), and c) mock job interviews (Time 1). The first research question, which is exploratory, focused on knowledge and skills acquisition, allowing statistical analysis [10-12]. Because communication skills are complex and highly context-dependent, they cannot be fully understood through a single method [13;14]. Thus, a mixed method approach is necessary, and we must use the external indicators of both types of data to determine our results [15]. These data were all collected after gaining approval from Texas Tech University's IRB. The total N was 25.

2.1 Data Collection

We had two sources of data for this section: the first was written hypothetical prompts that the students responded to at the beginning and end of the semester. These measures involve both written and spoken perspective-taking. The written hypothetical prompts can be requested from the authors. These data are both qualitative (word-based) and quantified. That is, we first analyzed them qualitatively, (see section 2.2.1 immediately below), but we also operationalized them by writing a five-point rubric with mutually exclusive elements for each score level.

Table 1: Data to Measure Objective and Subjective Communication Skills Growth

Metric	**What was it measuring?**	**When were the data collected?**	**Did it measure growth?**
Hypothetical Prompts	Formal and informal written communication skills	T0 and T1	Yes
Mock Job Interviews	Formal spoken communication skills	T1	No – only at T1

The second source of data is from interviews conducted at Time 1 in which students were asked to pretend that they were seeking a job as an AM engineer at a hospital. The scenario for the interview can be requested from the authors. Conducting structured, non-repeated, dyadic interviews (N=25, 10-25 minutes per interview) helped us achieve our goal of assessing their skills authentically [16].

2.2 Data Analysis

To analyze patterns within the mock job interview transcripts as well as the students' answers to the written hypothetical prompts, it was best to engage in a framework analysis, meaning that we were searching for recurring ideas (referred to as themes) within a data set [17-19]. The transcript analysis examined additive manufacturing knowledge, patient-centered professional framing, clinician persuasion, accountability, and communication during errors or defects.

To determine change, we used a t-test with equal variances because the sample stayed the same between T0 and T1 and the standard deviation for the two samples remained equivalent.

3. Results:

3.1 Knowledge and Skill Acquisition (Quantitative and Qualitative Data)

To measure this, the engineering professors involved in the project wrote a diagnostic quiz (this can be requested from the authors) that students took on the first day of classes (Time 0) and the final day of classes (Time 1). The quiz consisted of 10 multiple choice questions that only had one right answer and four short answer questions. The multiple-choice questions were worth two points each. The short answer questions were worth a possible five points each, to make the quiz range 0-40. Before blindly grading the short answer questions, the engineering professors developed a 0-5 rubric with specific and mutually exclusive elements for each question to determine the essay's score. The same professor marked the same question at T0 and T1 to be as similar as possible. At T0, the average score was 14.56 (6.48 multiple choice and 8.08 short answer). At T1, the average was 24.68 (8.96 multiple choice and 14.56 short answer). Using a t-test assuming equal variances, this difference is statistically significant (+10.12, p=.001). **We conclude that the students learned about additive manufacturing in a healthcare setting during this class.**

3.2 Results Regarding Written Formal Communication Skills – Objective Data

To be able to measure written formal, we provided the students with two hypothetical prompts at Time 0 and Time 1. The first was used to evaluate their communication skills when speaking with a healthcare professional, and the second with a colleague within their field. In the first scenario, the doctor and engineer are miscommunicating about a model created by AM. In the second, an engineering teammate is not fulfilling his part of the group work.

Using the methods spelled out in 2.1.1, we used these data to measure scenarios that proposed a problem and provided the opportunity to allow the students to use their communication skills to solve it. **We found growth over time within the students' communication skills, and their ability to converse effectively with professionals in other disciplines, and their colleagues.** An example of this growth can be seen in Table 2 below.

Table 2: Example of Same Student's Formal Written Communication Skill Growth

Time 0	**Time 1**
I'm sorry that I am unable to manufacture the models in that way at the moment, could you describe how you would like the models to function so that I can grasp how to implement your requests?	I believe there has been a miscommunication between us. To make the model to your specifications, I will need (more data or whatever I actually need). I would also like to meet with you about the specific ways we could make the model able to be disassembled.

As can be seen from the above, the student is more professional and clearer in his response. He attributes the error to miscommunication, which he actively attempts to solve in the next sentence. He also suggests an in-person meeting as needed. In this case, the error may or may not have been his fault, so he doesn't immediately apologize for the error. Specifically, we found that the students seemed to reflexively apologize at the beginning of the semester and always assume the fault was theirs. This may not actually be useful in stopping future errors, so we trained them to accurately diagnose the problem first, then take responsibility as needed.

Quantitatively, we found that the students improved significantly in the ability to take another's perspective and a related skill, and the ability to identify the problem. Using a t-test assuming equal variances, the score at T0 for perspective-taking averaged 2.48 and the score at T1 averaged 2.96 ($p=.04$). For the ability to identify the problem and using the same test, the score at T0 averaged 2.4 and the score at T1 averaged 2.84 ($p<.05$). We found that there were no significant changes in the section regarding grammar presenting a point to improve on in the future. However, there was a large change in the ability to take others' perspectives. For example, at Time 0, a student wrote:

> Ron, we have given you ample time and warnings to do your work for this. If you do not do your part we will all report you to the professor and request that you do not receive credit.

This does not show an ability to take Ron's perspective. This student is primarily giving harsh criticism for Ron's performance, which only furthers the problem. In contrast, at Time 1, the same student (to a similar but not identical prompt) said:

> I hope this email finds you well. I wanted to check in after receiving your message. **I understand life can be complicated but with the deadline just a few days away, it is imperative that we stay on track**. Since your section is critical for our final submission, **is it possible to work together**? If so, can you provide an update on what needs to be done?

Instead of blaming Ron, the student is trying to understand his issues and find a solution.

3.3 Results Regarding Spoken Formal Spoken Skills - Mock Job Interviews

Mock job interviews conducted at the end of the semester enabled the assessment of knowledge content on additive manufacturing and their ability to maintain a professional conversation with medical practitioners. Data indicate that students predominantly demonstrated a functional understanding of the technology by framing it as an effective solution to various medical demands. For example, at Time 1, in response to the first question of the mock job interview, a student said:

> I've been working with a few out of manufacturing 3D printing projects. There seems to be a lot of ways that it's applicable in the medical field. One of the big ones is for training surgical planning, something that's pretty easy to do with 3D printers, comparatively to some of the other stuff that you can do in the medical field is print models. Something like that would be very useful for surgical procedures and communicating with patients on what needs to be done.

Interviewees' responses demonstrated a descriptive approach when discussing additive manufacturing, reflecting the theoretical knowledge they gained in the class. But these responses lacked the ability to answer the so-what question, which professional communication requires in real-world situations, indicating the need for further development of persuasion skills and adaptation to different audiences, including patients and medical professionals.

4. Conclusion:

Our research questions asked i) whether the students grew in knowledge and skills of additive manufacturing focused on healthcare and ii) whether and how formal spoken and written communication skills grew. We saw a definite increase in the students' knowledge and skills, in that the student average increased by 10.12 points ($p<.001$) from Time 0 to Time 1. Quantitatively, as measured by the responses to written hypotheticals, we saw that students' ability to identify a problem and take another's perspective increased over the course of the semester in written formal skills. Qualitatively, in both the written hypotheticals and the response to the mock job interview, we saw a marked change in their students' confidence and facility in both formal written and spoken communication. We are particularly interested in the results that show a change in students' ability to take another person's perspective when trouble-shooting a problem. This indicates a skill change that is based in empathy, which should lead to more sensitive and efficient communication across disciplines in the future.

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