Improving Students’ Writing Skills by Integrating Prototyping Activities in their Writing Course

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Abstract
Writing is the most important means of communication in the engineering field. Although understanding the content of an engineering discipline is very important, engineers become much more appreciated if they know how to convey their expertise to a variety of audiences. This paper reports on a collaboration between a writing professor and Engineering Enrichment Program at an international branch campus in the Middle East. Over the course of three semesters, a technical and business writing course was redesigned by integrating prototyping, collaboration, and entrepreneurship skills.

Drawing upon survey data, we evaluate the effectiveness of our interdisciplinary, integrated approach to engineering education. From the perspective of writing and communication, students gained a stronger understanding of workplace audiences and expectations. Additionally, the experiential learning focus in the course engaged students in deeper reflective practices in both writing and engineering.

We conclude with recommendations for others redesigning courses and curricula for 21st century literacies and global entrepreneurship. We also examine future directions for the course in the coming years.

1.1 Institutional context and the study
Texas A&M University at Qatar launched the Engineering Enrichment Program (EEP) in 2014. EEP provides hands-on learning for our engineering students through extra-curricular courses during school breaks, innovative student-led projects, and professional skills training. These courses were originally meant to supplement the engineering curriculum at our institution by allowing students to learn crucial software and hardware programs at their own pace.

The long-term vision for the EEP is to add to its current collaborations with faculty, staff, and students through entrepreneurial and technical projects in the curriculum. We chose to start implementing this vision in a Technical and Business Writing course, and this paper reports on the pilot study of implementing prototyping skills into this course.

The larger study aims to foster institutional change and provide new knowledge on engineering education and entrepreneurship program development.

In this paper, we describe the ‘gaps’ in the curriculum we wanted to fill, the philosophy and assignments in the course, the methods we used to evaluate the course, and future directions for the project.
1.2 Writing and Engineering

Previous studies have examined ways to connect writing instruction with the professional development of engineering students, often integrating writing-intensive assignments into required courses for engineering majors [1] [2] [3] [4]. This intervention is often categorized as Writing in the Disciplines (WID), a well-established and evidence-based method for apprenticing students into the writing that will be required of them as professionals in their own particular field. WID programs rely on faculty members, often outside of the English department, to demystify workplace writing practices and discipline-specific conventions of genres. Another model, Writing-Enriched Curriculum (WEC) has shown success in having disciplinary faculty members take ownership of writing instruction in major courses [5].

WID programs often require students to have a fairly significant amount of disciplinary knowledge, so earlier courses in the curriculum tend to use different approaches towards connecting writing and engineering. Some courses incorporate both WID and Writing to Learn (WTL) as philosophies. Whereas WID focuses on disciplinary ways of writing and communicating, WTL uses writing and communication as tools to help students understand course material more effectively.

1.3 Engineering and Writing Collaboration

Technical and Business Writing (English 210) at Texas A&M University at Qatar is a required course for all engineering majors, and students often take it in their second year, meaning that WTL assignments are needed to scaffold students’ understanding of disciplinary forms of writing. English 210 is taught by faculty members with expertise in rhetoric and composition, technical and workplace communication, and English as a Second Language. None have previous experience as engineering practitioners, so effective WID assignments require collaboration with industry partners or interested and available engineering faculty members.

For their part, English 210 instructors at Texas A&M University at Qatar experienced problems helping students and faculty members understand the variety of genres required of engineers. Prior to entering the course, most students’ experience with writing in engineering courses was lab reports, written only for the professor and only for evaluation of students’ performance in the lab. While these assignments fulfilled the engineering professors’ purposes of assessing student learning, they did not adequately prepare students for non-academic audiences. English 210 instructors were therefore tasked with introducing students to workplace communication for a profession they had little experience with.

Thus, one of the problems we wanted to solve with our collaboration was to develop problem-based assignments for an industry audience within this writing course [6]. In addition to making the English course more relevant and rigorous for students, adding engineering design and prototyping projects to a course for second- and third-year students provided scaffolding for their capstone experience. As we describe in the next section, students received instruction and practice on writing and working productively in teams. By receiving feedback from both experts and non-experts, students also gained knowledge on writing for different audiences.
This course and our collaboration have aimed to foster larger changes at our international branch campus. The current curriculum is robust but largely traditional: no courses on entrepreneurship or design thinking are offered at Texas A&M University at Qatar. Some would say there is good reason to exclude entrepreneurship from the Texas A&M University at Qatar engineering curriculum, as the ecosystem for startups is just beginning to emerge in Qatar and has just started to take a foothold in the Middle East – North Africa region.

However, for the Engineering Enrichment Program director, this is the right time to add entrepreneurship and design thinking as extracurricular short courses to the program, or even to collaborate with course instructors on integrating these topics in their courses. Moreover, the program is currently expanding its collaboration to include many business incubators in Qatar, to be better aligned with institutional strategic initiative in teaching and learning excellence, and to be consistent with the mission and interest of Qatar National Vision 2030.

Rapid prototyping is the means by which entrepreneurs can quickly develop and realize their ideas into a product. Rapid prototyping is becoming a necessity to communicate the concept and technical features to potential investors and customers. In the Engineering Enrichment Program, students from multiple engineering disciplines are trained with all skills required to build a prototype within a remarkably short period of time; these skills include but are not limited to 3D modelling, laser cutting and 3D printing.

For the writing professor, the larger change she wanted to see was for students and faculty to make connections between writing and design. For both engineers and writers, the iterative practices of design are crucial to their success [7]. Both prototypes and the written communication that accompanies them are constantly evaluated and improved through feedback loops. However, popular perception suggests that “good” designs just appear in the inventor’s head, just as people might believe the myth that “good” writing appears magically in a student’s paper.

In order to apprentice students into their discipline, designers and writers often have to combat these influential narratives about how they work. This collaboration gave students the opportunity to reflect on “what really happened” when they worked as engineers to negotiate as a team, develop a prototype, and communicate their design ideas to others. The next section describes the course in more detail.

2.1 Description of the course

Over the course of four semesters, the pilot version of English 210 underwent a number of changes. The main structure remained the same: a semester-long project asking students to develop a prototype in an area of engineering design and present that prototype at a showcase at the end of the semester. The first semester, students were allowed to design for any engineering sub-discipline; the second semester had “Smart Cities” as its theme. In the third iteration of the course, students designed prototypes for the Challenge 22 competition in Qatar, and the most recent version of the course required students to innovate in the healthcare sector. In each of these iterations, three main areas of knowledge were addressed and assessed.
2.1.1 Collaboration skills

Early in the semester, students chose teams that were required to be diverse in terms of major, gender, and/or nationality. Teams consisted of 3-5 students who often formed because of shared interest in one of the ideas a member had put forward as a possible direction for their project.

Teams were required to draft and revise a team contract and a Gantt chart, as well as return to these documents throughout the semester for updates and reflection. In-class activities focused on constructive and destructive conflict, conflict resolution, different models of collaboration on writing assignments, and diverse communication styles. Students read a textbook on team writing and completed activities related to the topics in that textbook [8].

Although not a significant part of the original design of the pilot course, teamwork arose as an important area for instruction and practice. Collaboration was mentioned as one of the course outcomes, and student feedback and our observations suggested that these skills were not being explicitly taught as part of the engineering curriculum.

2.1.2 Project based writing

As part of their goal to develop a prototype, students were required to complete the following writing and communication assignments.

1. Problem statement: Teams were asked to write a proposal to a supervisor at work, documenting the problem they wanted to solve and evaluating the previous products or solutions to their problem.
2. Ideation presentation: Teams were asked to present to the class (fellow novice engineers) on the ideation process they used to come up with their initial prototype, and to seek feedback from their audience on decisions the team was currently struggling with.
3. Data analysis memo: Teams were asked to find a source of data (either primary or through data found in previous literature), represent it in graphs, and provide a short, written explanation of how this data related to the development of their prototype. In the first few versions of the pilot course design, this assignment was a longer report. Later additions to the curriculum made it difficult to spend a longer amount of time on data visualization and analysis, although the core instruction and practice on this topic remained.
4. Showcase presentation: At the end of the semester showcase, students were required to have three deliverables – their prototype, a poster explaining their project, and a short video inviting their audience to invest in their project, similar to those posted on the Kickstarter website.

The assignments above were completed as teams, but the documentation of the project was done by each individual student. Students submitted a Project Management Log which they updated throughout the semester with meeting minutes, in-class writing activities, reflections, sketches, and other forms of documentation that they were effectively managing their team project.

2.1.3 Prototyping

The most innovative aspect of the course was incorporating prototyping skills. Given that no other course directly taught these skills, the collaborators thought that this aspect of the study was crucial
to the success of both the course and the EEP. Teams wrote a memo to the director of the EEP early in the semester, outlining their initial plans for their prototype and requesting materials, personnel, and other resources.

Teams then communicated with the director as necessary throughout the semester, and the EEP provided teams with feedback and training specific to their project, such as 3D modeling using SOLIDWORKS and programming of Arduino or Raspberry Pi boards. Before the showcase, EEP staff assisted students with 3-D printing, wood cutting, or other fabrication methods for their prototypes.

2.2 Notable student projects

Table 1 below lists some sample projects which students produced in the summer and fall of 2017, after integrating the learnt prototyping skills. These prototypes were crucial to their final presentation to engineering faculty, students, and staff at the showcase.

<table>
<thead>
<tr>
<th>Project</th>
<th>Summary and Techniques used</th>
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</thead>
</table>
| Biometric Watch  | • Prototyping a watch model via 3D printing to investigate packaging the sensors in a small space of the wearable watch.  
                     • The students used 3D modelling to design the parts of the watch and 3D printed the mechanical casing and interface the sensors. |
| ASOS Health prototype | • The ASOS device takes a blood sample and tests the content, giving users information of their blood profile and indicating any health conditions.  
                                • This team designed the device in 3D and fabricated the mechanical enclosure of the demo using laser cutting. |
### Portable AC
- The Portable Desktop Air conditioning unit is meant to provide a safer work environment by moderating the impact of successive heat waves by cooling the body and controlling humidity.
- Prototyping a demo to give a sense of the scale to potential users. Used 3D modeling, 3D printing and laser cutting to prototype a motor powered unit.

### Holomatch
- Recreate a hyper realist 3D image of football matches.
- Manufactured a small prototype to project the hologram from tablets.
- Students 3D printed the frame and laser cut the reflective acrylic sheets.

### Easy Well
- Well drilling DIY kit
- The students manufactured a scaled down prototype as a demo.
- The whole design was CAD modeled. Some parts were 3D printed and others were machines.

### 3.1 Method of evaluation
We evaluated the pilot project using a survey that was distributed to measure student attitudes towards entrepreneurship and students’ perception of their workplace writing abilities. The survey was intended to evaluate if the students saw improvement in their workplace writing skills and if they would be interested in pursuing entrepreneurship projects (such as the extracurricular ones led by the EEP) after the course. The following sections provide more details about the method of evaluation and the student population.

### 3.2 Post-semester survey of student attitudes towards entrepreneurship and writing
A survey was developed using items from the Engineering Entrepreneurship survey [9] and APPLES (Academic Pathways of People Learning Engineering Survey) [10]. From the
Engineering Entrepreneurship survey, we chose items that measured students’ interest in entrepreneurship and assessment of their own abilities to do that work. From APPLES, we chose items related to workplace communication. The full survey can be found in Appendix A.

The survey was distributed at the end of spring 2017 semester. Sixteen students were enrolled in the class, and 12 took the survey. Survey respondents were anonymous, and participants were allowed to skip questions.

Table 2. Demographics of Survey Participants

<table>
<thead>
<tr>
<th>Gender</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>5</td>
</tr>
<tr>
<td>Female</td>
<td>7</td>
</tr>
<tr>
<td>Mechanical</td>
<td>3</td>
</tr>
<tr>
<td>Chemical</td>
<td>6</td>
</tr>
<tr>
<td>Electrical</td>
<td>3</td>
</tr>
<tr>
<td>Freshman</td>
<td>3</td>
</tr>
<tr>
<td>Sophomore</td>
<td>8</td>
</tr>
<tr>
<td>Junior</td>
<td>0</td>
</tr>
<tr>
<td>Senior</td>
<td>1</td>
</tr>
</tbody>
</table>

4.1 Results from survey

Overall, the survey participants (n=12) reported satisfaction with their experience in the course, as 92% agreed or strongly agreed that they liked their project; one neither agreed nor disagreed, as seen in Figure 1. One participant wrote in response that “I believe that my professor [has] made an exceptional job in organizing the process of our innovative project. I had a wonderful experience in working with my group and help[ing] build our idea.”

![Figure 1. Student Satisfaction.](image)
All survey participants expressed interest in learning more about entrepreneurship in their engineering courses (see Figure 2). However, only five participants (41%) agreed that they were interested in starting their own business or be self-employed after graduation. This result can be explained by the fact that some students had obtained sponsorships from local companies to attend university. Therefore, the possibility of using their knowledge from the course to create their own business was unlikely.

Figure 2. Perceptions Towards Entrepreneurship.

For the questions about students’ self-reported confidence in completing writing tasks, survey participants reported greater confidence in writing tasks involving technical matters in the workplace (memo or email), as seen in Figure 3. In contrast, one-third of participants were not sure they could compose a business plan.

Figure 3. Confidence in Future Writing Tasks.
Figure 4 shows that after the course, students expressed confidence in their ability to lead a technical team developing a new product (83%) and to translate user needs into a requirement for a design (92%). These are remarkable findings for a writing course and reflect the development of the students’ prototyping skills.

Survey participants expressed strong confidence in their ability to collaborate on their writing, with 58% feeling really confident about evaluating someone else’s writing and 67% feeling really confident about helping a colleague with their writing, as seen in Figure 5.
4.2 Lessons learned from the EEP

The technical presentation of students benefited from prototyping in many ways. We believe that the presentation and prototyping building skills are complementary and both are essential for the completion and success of any project. By having the prototype in hand, the students’ poster and PowerPoint presentations were more interactive with the audience. The prototypes were a powerful tool to attract attention of the audience as they show the strong potential and practicality of the ideas. Having a prototype on exhibit incentivized the audience to engage in discussion as it reflects a level of commitment by students to the project.

Many of the ideas presented by the students had strong potential for future development due to being effective solutions to challenges in many vital fields. By producing the first prototypes, students had an opportunity to understand the engineering challenges they may have to overcome to have fully functional prototypes if they decided to take their idea further.

Building the prototype is a crucial first step to convince investors, customers and peers to introduce, design and iterate products before being released to the markets. Having several iterations is vital to get customers’ feedback and analyze strengths and weaknesses of the design. The collaboration between the writing course and EEP enabled the students to have a quick introduction into this perspective.

The Maker Movement is changing the way we conduct our day to day business, as well as in shaping consumer mindsets and education standards. Academic institutions in Qatar need to adapt these cultures to become more innovative and creative contributors to the growing Qatar community.

4.3 Lessons learned from the writing professor

After teaching the course for a year and analyzing the survey results for this paper, the writing professor saw an increase in both student engagement and student ability to learn workplace communication skills.

English and technical writing faculty members often teach students that writing is rhetorical, and that their communication, in terms of both content and style, has to respond to the context of the writer’s situation. While learning can and does happen in courses without attention to context, scholarship in writing transfer shows that explicit rhetorical education and instruction on how writing operates in communities can foster students’ ability to apply writing knowledge to new contexts [11]. By integrating prototyping into the writing course, we fostered opportunities for students to understand the rhetorical context of their work as teams, and in turn, reflect on how that writing knowledge could be extended into the workplace.

Prototyping helped students see the “real work” of engineering and sparked their interest in new applications of their coursework. According to the survey administered after the course, students felt confident about completing workplace writing tasks, especially those related to their technical knowledge.
5.1 Conclusion and next steps

In this paper, we have reported on a pilot study which integrated prototyping skills into a technical writing course. Students reported satisfaction with the project-based learning and writing content used in the course. The prototypes developed during the course introduced students to new applications of their engineering knowledge and gave them important practice in their communication skills.

We plan to expand the strategies used in developing this pilot by using the resources in the EEP to support and encourage faculty in both technical and non-technical courses to incorporate prototyping into the curriculum. By integrating Maker Movement strategies into these courses, the arbitrary boundaries between extra- and co-curricular learning dissolve, and students take initiative over their own learning.

6.1 References


Appendix A

Integrated Engineer Survey

Q1 Please indicate your major.

Q2 Please indicate your intended minor, if applicable.

Q3 How many years have you been enrolled at TAMUQ? Include the current academic year as one year.

Q4 Please indicate your gender.
   - Male
   - Female

Q5 How would you describe your nationality or ethnic background?

Q6 Please indicate how strongly you agree or disagree with each of these statements.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree (1)</th>
<th>Somewhat agree (2)</th>
<th>Neither agree nor disagree (3)</th>
<th>Somewhat disagree (4)</th>
<th>Strongly disagree (5)</th>
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</thead>
<tbody>
<tr>
<td>Creative thinking is one of my strengths. (1)</td>
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<tr>
<td>I am skilled at solving problems that have multiple solutions. (2)</td>
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<tr>
<td>I have a general interest in the subject of entrepreneurship. (3)</td>
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<tr>
<td>I would like to learn about entrepreneurship in my engineering courses. (4)</td>
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<td></td>
<td></td>
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<tr>
<td>I plan to start my own business or be self-</td>
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</tbody>
</table>
employed after graduation. (5)
I liked working on my project in ENGL 210 this semester. (6)

### Q7 For each statement, indicate how confident you are that you could perform that skill or ability at an engineering workplace.

<table>
<thead>
<tr>
<th>Skill Description</th>
<th>Really confident (1)</th>
<th>Confident (2)</th>
<th>Not sure (3)</th>
<th>Not confident (4)</th>
<th>Really not confident (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write a clear and complete business plan</td>
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<tr>
<td>Write a technical memo or email</td>
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<tr>
<td>Lead a technical team developing a new product</td>
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<td>Translate user needs into requirements for a design</td>
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<tr>
<td>Manage a diverse team of different genders and/or nationalities</td>
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<tr>
<td>Resolve conflicts in a team</td>
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<td>Provide a graph or chart for a report</td>
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<tr>
<td>Evaluate someone else's writing or presentation</td>
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<tr>
<td>Help a colleague with their writing or presentation</td>
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</table>

Q8 Do you have any specific feedback for your professor or the EEP staff?