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Writing to Learn Engineering: Identifying Effective Techniques for the Integration of Written Communication into Engineering Classes and Curricula (NSF RIGEE project)

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Abstract

The inclusion of writing-based exercises in technical courses has multiple learning benefits to students. Writing exercises not only serve to improve students' written communication skills (i.e., "learn to write"), but can also be leveraged to develop critical thinking skills and promote deeper understanding of technical concepts (i.e., "write to learn"). Nevertheless, while writing-intensive assignments are relatively common in upper-level technical courses, especially in the form of laboratory and project reports, writing is often absent in the larger, required core courses that are taken by large numbers of engineering students. This is a missed opportunity to both enhance student learning of technical content as well as missed chance for students to have more writing practice. This NSF RIGEE project aims to investigate, support, and promote the inclusion of writing in technical courses, particularly introductory and core courses. Analysis of an engineering instructor survey carried out as part of the project revealed concerns about assessment and feedback on students' written work. Additionally, writing instructors were interested in the creation of guides designed to aid instructors in the creation and tailoring of writing prompts for use in their existing technical courses. This paper introduces preliminary resources we have created in response to these stated needs, in order to help instructors develop, implement, and assess writing assignments in their courses. Current resources include a decision tree to help instructors create writing assignments within their classrooms and assessment rubrics that can easily be adapted to specific writing assignment needs. Resources will continue to be developed during the remainder of the project, culminating in a writing website geared towards instructors.

Introduction

Although writing is important in engineering education and practice, assigning writing activities in engineering courses can strain instructor resources. For example, a writing assignment assigned in a large engineering class, which often have more than 100 students, could require many hours of time devoted to assignment development, rubric development, grading, and feedback. However, we hypothesize that the development of writing assignment-related resources for faculty can help decrease the time sink and lower expertise barriers, thereby making writing assignments seem less daunting for instructors looking to incorporate them into their courses, leading to more inclusion of writing-based assignments in engineering classes.

Many universities already have online writing centers that aim to help with various aspects of writing. Typically the websites for such centers are divided into information for students and information for faculty, with many sites focusing entirely on one aspect while neglecting the other. For example, schools like the University of Nevada, Reno and University of Maryland University College have writing centers where faculty resources primarily focus on informing faculty about available resources their centers can provide to students, such as sample assessments and workshops [1] [2]. These materials are valuable for students to use once writing is assigned, but they provide little guidance for instructors looking to create or assess their own writing assignments. The James Madison University writing web site similarly emphasizes the

mentoring available for students, but it also includes a few guidelines for faculty to help create effective writing assignments and develop group writing assignments that encourage collaboration [3]. The Purdue University Online Writing Lab takes this a step further by providing in-depth writing information and tutorials targeted towards students, faculty, staff, and the general public [4]. Although no resources are posted on the web site to explicitly help instructors incorporate more writing in their courses, the site does offer teaching services for one-on-one help to support such objectives.

The University of North Carolina at Chapel Hill writing center provides helpful resources for tackling common roadblocks facing faculty attempting to include writing education within their classrooms [5]. The faculty writing center provides tips on teaching writing, such as ways to identify good writing, descriptions of different student writing backgrounds including for ESL students, and examples of ways to incorporate writing into classes. The writing center web site appears to be an excellent starting point for teachers interested in incorporating writing, but the resources seem geared more towards methods for helping students "learning to write" as opposed to "writing to learn," which is also a prominent goal for many engineering instructors. Additionally, although the writing center does stress its availability to help mentor students, there is no information provided on assessment or feedback methods, which is often a significant area of concern among teachers who assign writing.

One of the most thorough faculty resources identified by the authors was the Cain Project by Rice University [6]. This ten-year project provided written and oral communication help to faculty and students. And while the Cain Project does emphasize availability for in-person mentoring help, similar to other online writing centers, it also stresses help for faculty who are looking to add more writing to their classes. Examples of courses using the Cain Project at Rice University are available for instructors to review, including brief descriptions of assignments the Cain Project helped initiate with the course instructors. A helpful component not featured on many other websites is the grading and feedback forms provided to the instructors. The forms appear to mimic the analytic rubric style by dividing assessment into subcategories and asking instructors to assign achieved points to each along with a section to include additional feedback. The assessment and feedback forms are designed to be applicable to a wide variety of material and could be applied to many courses.

The forms provided by the Cain Project, however, are all designed for longer, more traditional project deliverables like presentations and full reports. These types of assignments are commonly used in engineering classes [7], but assessments designed for these longer reports may not be applicable to other types of shorter writing assignments. This limitation may make these resources difficult to apply to the shorter, paragraph-length types of writing exercises that can be assigned on a regular basis throughout the length of the course without overburdening the instructor. House et al. (2009), in reporting on writing activities at Rose-Hulman Institute of Technology, provided a rare example of an actual rubric for this kind of short, homework-type writing assignment [8].

Beyond the websites described here, there remains a lack of easily available and transferable resources for instructors looking to implement writing education within their undergraduate engineering courses. Particularly lacking are resources to support short writing assignments

geared toward student learning of technical content. One of our project aims is to develop and disseminate these resources on a website; in particular, we initially aim to develop resources that will:

- Aid instructors in creating short, easy to implement writing assignments. Related resources will include a "menu" of writing prompts, linked to different learning objectives that may be of interest to an instructor. These prompts are designed to be readily customizable to any course, and as such, we believe them to be transferrable.
- Aid instructors in the adopting of a grading rubric, either holistic or analytic, that is simple for students and instructors to understand and apply.

Developed Resources

Developing an Assignment

Traditionally, writing assignments in undergraduate engineering courses have centered on lab reports and project reports [7]. Although these assignments can be beneficial, they are very time consuming for both the students and the instructors. Instead of lengthy, traditional assignments, this project recommends the use of shorter writing prompts that can be selected based off of the instructors desired learning outcomes. The decision tree shown in Figure 1 starts with guiding instructors through selecting a type of writing question. Writing questions are divided into five subcategories: Explain a Concept, Explain a Problem, How Stuff Works, Real World Example, and Pick a Side.

Explain a Concept For Explain a Concept questions, instructors are asking students to explain different terminology, equations, and theory in their own words. These types of problems typically involve minimal deep thinking on the students' parts, and answers are often found within supporting texts such as textbooks. Example: "In your own words, explain the meaning of Bernoulli's equation."

Explain a Problem Instructors looking for students to understand the reason behind solutions to problems can opt for assigning Explain a Problem questions. Explain a Problem questions are potentially the easiest to assign because they can be created simply by placing the words "Explain" or "Why?" at the end of any calculation based problem. Example: "Calculate the maximum velocity achieved by wheel A and wheel B. Explain why they are different." The format of such explanations can be as detailed or simplistic as the instructor desires.

How Stuff Works Assigning problems that ask students to explain how different objects work helps students link classroom concepts to concrete objects, in turn reinforcing the real-world applications of their learning. How Stuff Works problems require students to understand concepts in more detail compared to previously discussed writing questions. Example: "How does an air compressor work?" The instructor can prompt students with concepts to include, or leave the problem open-ended.

Real World Example Similar to How Stuff Works problems, a Real World Example question requires students to link theory and concepts they have learned in class to objects they interact with on a regular basis. The level of learning required for Real World Example problems is higher than Explain a Concept or Explain a Problem, and help students connect knowledge to practice. Example: “Explain for the water distribution system of a tall building works, and use a specific example to help illustrate.” These questions are effective at linking classroom material to actual examples, which is an important motivator for student learning.

Pick a Side Assigning Pick of Side problems require students to link information learned in class to real world situations, but also requires them to take learning a step further and defend a particular side. Typically these questions look at engineering problems from a broader perspective like the environmental, societal, or political viewpoint, and as such are good questions for addressing learning outcomes beyond the technical concepts. Example: “Choose an environmental, economic, or societal standpoint, and argue for or against the construction of the Keystone XL Pipeline.”

Our first set of developed resources are aimed at supporting instructors in the inclusion of paragraph writing tasks in their large engineering courses. In order to help instructors navigate the steps towards implementing writing education in their classes, we developed a flowchart focused on achieving learning outcomes by selecting the best type of writing prompt, assessing that writing consistently and fairly, and providing resources to students.

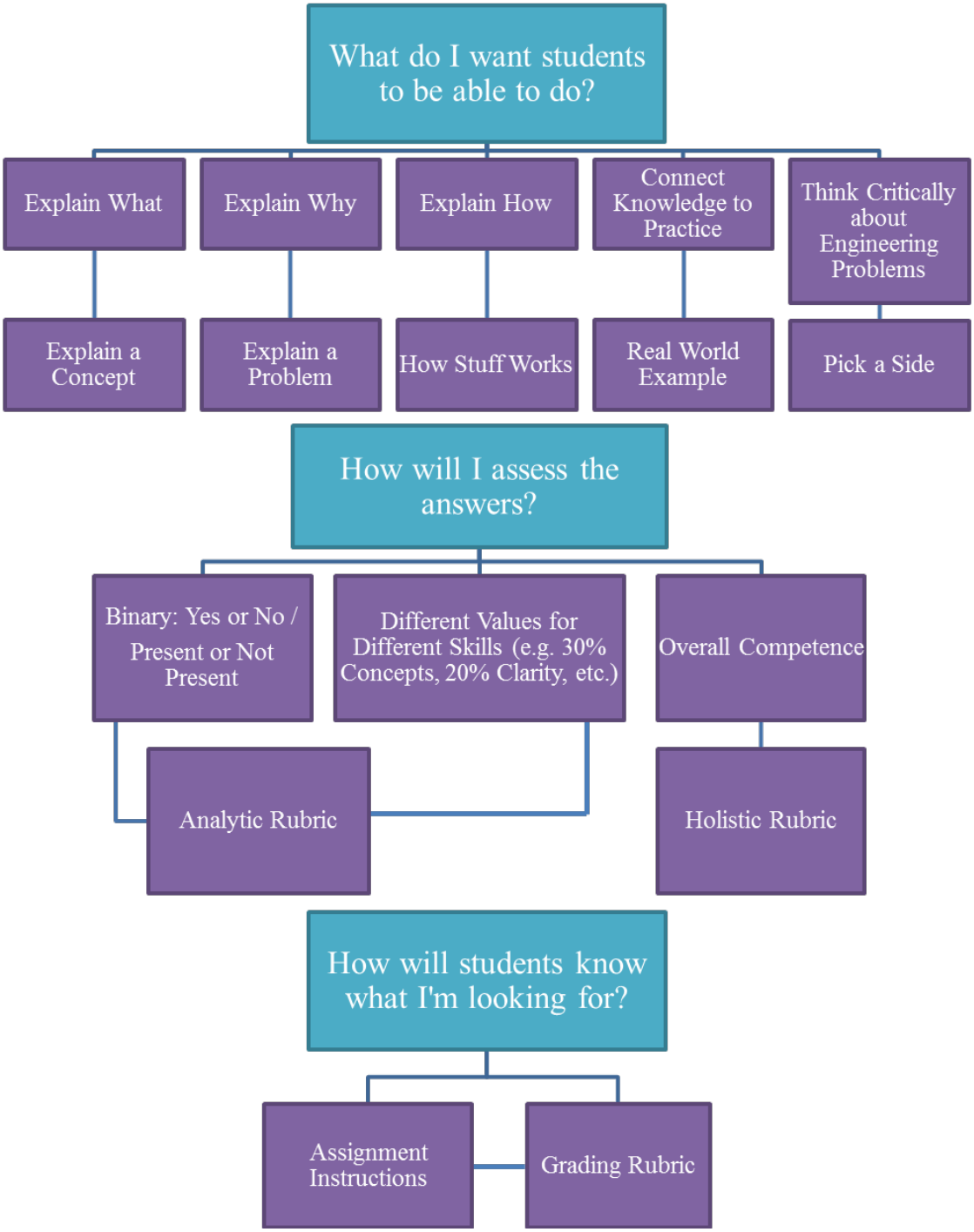

Figure 1. Flowchart for designing a writing assignment

Figure 1 allows instructors to simplify the task of creating an assignment, while also illustrating a condensed menu of options for each step. More specifically, three main steps are highlighted in the flowchart: (1) Deciding on the type of writing question by choosing the desired learning outcome, (2) Choosing a method of assessment, and (3) Identifying what resources will be provided to students. This chart does not include all potential options for creating a writing assignment, but aims to simplify the process into useful and easily digestible pieces. To supplement the flowchart, we will ultimately include a complete example that moves all the way through the decision tree, with website links on each portion of the tree.

Feedback and Assessment

Constructive, effective feedback and assessment is a necessary component of successful writing assignments, but is a constant time sink for instructors. But without good and prompt feedback, students have difficulty improving and can become frustrated. Our project proposes the use of rubrics to speed and standardize the process of grading written assignments. In a study conducted by Essig et al. (2014) the use of rubrics, combined with a minimal marking scheme, allowed for assessment and feedback of paragraph writing assignments to be limited to 2-3 minutes grading time per student [9]. House et al. (2009) concluded that as an instructor became familiar with a rubric, almost no extra time was added to the grading load on "explain-a-problem" type short writing assignments [8].

The most common rubrics can be classified as either analytic or holistic rubrics. Analytic rubrics are typically more detailed and break down scores into specific categories chosen by the instructor, as in the example provided in Figure 2.

ANALYTIC RUBRIC	
Correctness of answer	/30
Quality of support/explanation	/20
Mention of at least two concepts	/20
Spelling and grammar	/20
Documentation	/10
TOTAL	/100

Figure 2. Example of a simple analytic rubric

Instructors are able to customize analytic rubrics by selecting specific categories that coincide with the ultimate goals of a particular assignment. Additionally, changing the point values assigned to each category allows for instructors to tweak the emphasis of assignments. For example, if an instructor wants to stress the importance of supporting answers with existing research, than the Quality of Support/Explanation category seen in the example could be assigned a greater number of points. An instructor wanting to emphasize the technical content, on the other hand, could add additional points to the Correctness of Answer category.

Alternatively, instructors can use a holistic rubric to simplify the assessment process into overall point values [10] [11]. An example of a holistic rubric is shown in Figure 3.

HOLISTIC RUBRIC

5: Excellent. All requirements met, correct content, insightful analysis/explanation, clear writing, very few errors.

4: Clearly competent. All requirements met, content was mostly correct, analysis/explanation present with some (but not excellent) support; minor writing errors may be present.

3: Satisfactory. Paper met all requirements. Content might have minor errors, and analysis/explanation might be simple or shallow, with basic to sketchy support. Some writing errors present.

2: Unsatisfactory: Paper was missing one or more requirements (e.g., major inaccuracy). Analysis might be unsupported or missing. Several writing errors present.

1: Serious difficulty: Paper was missing multiple requirements or completely failed to follow directions of the assignment. Distracting writing errors made paper difficult to read.

Figure 3. Example of a simple holistic rubric

The benefit to using a holistic rubric is the ease with which it can be applied to many assignments. Minimal to no adjustment is needed to the example rubric in order to apply it to different assignments; however, instructors would need to write very clear assignment guidelines and expectations for specific assignments in order to minimize student confusion and frustration about the parts of the rubric about assignment "requirements."

Conclusions and Future Work

This paper provides a glimpse into the resources and support our group envisions for engineering instructors as they work towards including more writing in their courses. Our main goals are to support instructors with easy to use information that can supplement their current teaching practices while not requiring large amounts of time for assignment creation and evaluation rubrics.

As the project continues, the development and cultivation of important resources will be finalized and made available online. Further work includes the development of short how-to guides for instructors to use in the formation of writing assignments. In particular we will develop instructions on the creation of writing questions including descriptions of different types of questions and existing resources and examples.

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