

# Writing as an essential tool to teach environmental engineering design concepts

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## Abstract

Writing in engineering courses provides a mechanism for processing scientific information related to an engineering issue and synthesize sound solutions through a descriptive narrative often including sound engineering judgement or justifications, outstanding contributions and key conclusions. Some critical findings and contributions may not be recognized unless they are presented through a formal writing narrative. The Accreditation Board for Engineering and Technology (ABET) criterion 3 has stipulated the engineering education outcomes (f) through (j) which are intangible. These intangible ABET outcomes can be better accomplished by providing writing assignments to engineering students. In our civil engineering senior design elective course, CE4883-6883:Engineered Environmental Systems, various types of writing exercises such as informal writing, free writing, exploratory writing, formal writing, project report, and reflective writing were provided to enhance students' knowledge of the subject matter. Student learning experiences and the effectiveness of writing exercises to meet ABET outcomes were discussed in this paper.

## Keywords

Engineering education, environmental engineering, engineering design, student learning, and writing

## Introduction

The ability to write is often considered merely as a communication skill, while this is true, writing can be used as a tool to achieve more meaningful and specific objectives in engineering education. For instance, the ABET Engineering Criteria program has defined the specific outcomes for the engineering programs which include outcomes (a) through (j) (see Table 1). Some of these outcomes especially (a) through (e) are easy to accomplish. However, objectives (f) through (j) are not. These are intangible outcomes which need specific and tailored exercises to be effective<sup>1</sup>. These outcomes are listed as; (f) An understanding of professional and ethical responsibility, (g) An ability to communicate effectively, (h) The broad education necessary to understand the impact of engineering solutions in a global and societal context, (i) A recognition of the need for and an ability to engage in life-long learning, and (j) Knowledge of contemporary issues. While outcome (j) seems to be a tangible outcome, it may be difficult to measure in a conventional evaluation format. Outcome (k) can be considered is an tangible outcome as well.

Besides the program outcomes, civil and environmental engineers need to develop their critical thinking skills as majority of the projects they deal within the profession affect the society and the environment which present complex issues over time. Critical thinking skills are usually practiced to solve ill-defined, open-ended, complex problems through the analysis and evaluation of information, evaluating arguments, and developing conclusions resulting from sound reasoning. These complex problems are typical of those encountered in professional engineering practice, and require the reflective, self-regulatory judgment exemplified by critical thinking<sup>2-4</sup>.

Development of critical thinking skills is essential to achieve the ABET criteria outcomes. The intangible ABET program outcomes and the critical thinking skills can be fostered through a variety of hands-on and real-world engineering projects and activities<sup>5</sup>. However, it may not be possible in all cases due to resource and time related constraints. These two major goals can be accomplished by incorporating writing exercises. Bean defines seven ways to implement critical thinking promoting exercises which include<sup>6</sup>: (1) Problems presented as formal writing assignments, (2) Problems presented as thought-provokers for exploratory writing, (3) Problems presented as tasks for small group problem solving, (4) Problems presented as starters for inquiry-based class discussions, (5) Problems presented as think-on-your feet questions for in-class “cold calling,” (6) Problems presented as focusing questions for in-class debates, panel discussions, cases or fishbowls, and (7) Problems presented as practice exam questions. It is clear from the list that writing is central to the first two of these ways and implicit in several others. Since writing can be a process of thinking critically and a means for communicating the results, writing in an engineering curriculum can provide the mechanism for achieving the ABET outcomes mentioned above.

### **Writing exercises**

Writing assignments were used to create a practical context that deepens their understanding and comprehension of the content area<sup>7-9</sup>. The sequence of assignments designed in this study progressively advances students from solving single solution problems to more complex open-ended problems that more closely resemble the engineering design process. The following writing exercises were given to reinforce the course material through critical thinking and reflective thinking.

***Free writing*** – students were asked to write freely without a concern for sentence structure, grammar, logic and continuity, and scientific merit or technical correctness of the topic. Students were given 10 minutes to think and write on a topic of their interest. This is a classroom exercise.

***Exploratory writing*** – students were asked to provide a short essay of 500-1000 words on a topic of their interest within the course content.

(Topics covered by students – Pervious Concrete Pavements, Wetland Conservation, Low Impact Development, Validity of LID Stormwater Management Strategies, Stormwater Best Management Practices, Illicit Discharges, LID as an Alternative to Traditional Stormwater Management Practices, Combine Sewer And Overflows, Erosion and Sediment Control, Environmental Site Assessment, National Pollution Discharge Elimination System, Total Maximum Daily Loads, Leadership in Energy and

Environmental Design, The Use of Green Roofs for Stormwater Management, Residential Stormwater Quality Controls, Biofilters, Sewer Overflow Solutions, Watershed Biological Impairment Remediation, Yazoo River Levee, Benefits of Separate Sewer Systems, Computer Modeling Saving the Day, Water Conveyance Systems Separate or Together?)

**Informal writing** – A critical review of the existing storm water management practices and alternative practices for facilities in any one of the standard industrial sectors (up to 1000-1500 words).

**SWPPP Report (Formal Writing)** – A technical report encompassing the storm water pollution prevention plan for a given site and a justification essay for the design or selection of the best management practices. This exercise included a peer-review and a revision stage prior to submitting the final draft.

**Reflective writing** – An exercise to reflect on one’s own learning process through writing exercises to acknowledge strengths and weaknesses and the areas for improvement (750-1000 words).

The relationship between different ABET outcomes, writing exercises and the Bean critical thinking tasks are shown in Table 1. Bean critical thinking tasks 1 and 2 can be utilized to provide formal and thought-provoking exploratory writing exercises which promote critical thinking in students and in turn the ABET program criterion 3 outcomes.

Table 1. Relationship between the ABET Criterion 3 outcomes, writing exercises and the Bean critical thinking tasks

<b>ABET Criterion 3 Outcomes</b>	<b>Writing Exercise</b>	<b>Bean critical thinking task</b>
(a) an ability to apply knowledge of mathematics, science, and engineering		3, 5, 7
(b) an ability to design and conduct experiments, as well as to analyze and interpret data		3
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability		3, 4, 6
(d) an ability to function on multidisciplinary teams		3, 4, 6
(e) an ability to identify, formulate, and solve engineering problems		3, 7
(f) an understanding of professional and ethical responsibility	<b>Formal Writing SWPPP Reflective Writing</b>	<b>1, 2</b>

(g) an ability to communicate effectively	<b>SWPPP, Critical Review</b>	<b>1, 2</b>
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	<b>Critical review, Reflective Writing</b>	<b>2</b>
(i) a recognition of the need for, and an ability to engage in life-long learning	<b>Free Write Exploratory Writing</b>	<b>2 2</b>
(j) a knowledge of contemporary issues	<b>Critical review, Reflective Writing</b>	<b>2</b>
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	<b>SWPPP, Critical Review</b>	<b>1, 2</b>

## Results and Discussion

A “free-write” exercise was given to initiate the writing activity in the class. Free write exercise allows one to put together the thought process without a concern for grammar and punctuation. The goal is to put together an outline or random thoughts about the topic of interest which may eventually be used to develop a well-thought out final draft. Students were asked to write about their writing experience in this exercise. A few samples of student responses are shown below (unmodified). This is a work in progress study, meaning that some of the exercises are yet to be completed and the final output is to be evaluated at a later stage.

Student experiences were gathered through their opinions (short summary less than 100 words) after each exercise. 28 responses were received for this exercise. A summary of student experiences is reported in Table 2. It can be noted that half of students (50%) expressed that they enjoyed the writing exercise and learnt a lot from it due to the freedom to choose the topic of interest and research and learn more about the subject. Because specific guidelines or organization/structure requirements were not provided, many students struggled to define the topic and scope of content for the writing exercise. Reasons for various experiences are also given in Table 2. Lack of guidelines for the structure and expectations for the final product seemed to cause some confusion and increase complexity of the writing exercise.

Student responses on the “Free-Write” exercise

*“By quickly trying to put down ideas, a lot of questions were raised. By raising these questions new avenues for what can be written or what this paper needs to answer became clear. This also gave me ideas for how the paper could be introduced and what background information the readers might need. Although I don’t know how well this approach would work for a topic I know less about already”*

*“Helped me to quickly gather my thoughts and gave no time for second guessing. I think it would be good to use this exercise to highlight some major points/ideas but there is not enough time to provide sufficient detail. This process can be used to form an outline”.*

*“Can be good for getting past the initial hurdle of starting the paper”*

*“ I personally struggle when writing with trying to write exactly what I want rather than writing what I am thinking and going back to edit and polish. I think using this method for future writing will help me not only save time, but better communicate ”*

*“This exercise really helped me clear my mind of random thoughts and focus more on something that is very important to me. It helps me see what truly matters to me as an individual and what drives me. These are some of the most difficult to discover things in modern society, i.e. clear mind and sense purpose. I will definitely do this in my free time more often.”*

*“This exercise shows what is at the front of my mind. It helps me to gather my thoughts before I refine my paper and see which direction I want to go with the paper.”*

*“I would personally like more of these because it helps reinforce the material learned. It is a recap-assignment, if you will”*

*“This exercise was a little strange but I enjoyed doing it. Showed me my knowledge on this topic. Unfortunately I feel this was not an effective assignment and further enhance my knowledge with topic, but again, it was fun. Learned that my train of thought get “derailed” after a while from thinking about a part of the topic that is off topic. Not so sure if I would want to do this again.”*

*“In my opinion, the free-writing exercise is helpful to show an individual their knowledge about a topic that used to be unfamiliar with at the beginning of the semester.”*

*“In my opinion, this exercise is helpful for students to understand what they are interested in. if you are put on the spot to write something you realize how much prior knowledge you have in the subject. It is also helpful when trying to get a rough draft of a paper or something if you are stuck on an idea and don’t know how to continue.”*

*“I like this exercise. It made me feel productive to actually put thought to paper. It also made me discover what areas of LID I needed to learn more about, i.e. if I struggled to describe examples. I should probably study it more. All in all, this is a good exercise to discover what knowledge one has retained and what one needs to study more”*

Table 2. Summarized student responses to critical review writing exercise

<b>Experience</b>	<b>Number of participants</b>	<b>Remarks</b>
Enjoyed the exercise	6 (21.4%)	Freedom of topic, knowledge enhancement, research opportunity, in-depth understanding of the subject

Learnt a lot from this exercise	8 (28.6%)	Learnt more about the subject matter, BMPs, storm water issues, freedom to learn on our own
Interesting exercise	1 (3.6%)	Research opportunity
Struggled with the exercise	3 (10.7%)	Difficult to write, scope of the paper was not clear, prompt was not given, length of the exercise
Confused about the exercise	2 (7.1%)	About the expectation and the topic, no guidelines, ambiguity of the final product
Helpful to learn	3 (10.7%)	Topics were interesting and easy to learn, research opportunity helped
OK, Did not mind	4 (14.3%)	Lack of guidelines, realize to become a good writer
Not interested	1 (3.6%)	Busy schedule, know enough about writing

One of the four effective writing strategies suggested by Sharp et al includes peer-editing<sup>10</sup>. We have conducted a peer-review session to provide feedback on the storm water pollution prevention exercise. An evaluation form was provide to guide the peer-review process. Figure 1 shows the involvement of civil and environmental engineering during the peer-review exercise.



Figure 1. Civil engineering students performing peer-review on SWPPP report

A revised final draft of the storm water pollution prevention report was submitted following the peer-review session. A reflective writing exercise is given to provide the students with an opportunity to critically evaluate their learning experiences to assess what had worked and what has not, and topic areas for improvement.

## Conclusions

The importance of integrating writing assignments to teach environmental engineering concepts from the perspective of developing critical thinking skills and the ABET engineering education outcomes were discussed with exercises and the student feedback. This being the first attempt to implement different writing exercises, we identified several areas for improvement in guiding student learning process through writing exercises. These include a more structured guidelines on format and content requirements and scope definitions for individual exercises. This leaves opportunities for continuous improvement and thus learning and teaching experiences in the years to come.

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Veera Ganeswar Gude is an assistant professor of civil and environmental engineering at Mississippi State University. He has over 15 years of academic, industrial, and research experiences in chemical and environmental engineering projects. His research interests include algal biofuels, bioelectrochemical systems, desalination, and sustainability. His educational research focuses on enhancing critical thinking skills and metacognitive abilities in civil and environmental engineering students. He is the recipient of teaching excellence awards including 2015 National James M. Robbins Teaching Excellence by Chi-Epsilon, 2016 ASEE-SE Section Outstanding Faculty Research and 2016 ASEE Early Career Award from Env. Eng. Division.