Integrating Writing to Teach Engineered Environmental Systems Design

Dr. Veera Gnaneswar Gude P.E., Mississippi State University

Veera Gnaneswar Gude is a faculty member of civil and environmental engineering department at Mississippi State University. He has degrees in chemical (B.S.) and environmental engineering (M.S., Ph.D.) disciplines with over 10 years of academic, industrial, and research experiences on various chemical and environmental engineering projects. He is a licensed professional engineer and a board certified environmental engineer. His passion for teaching continues for over 10 years since his graduate school. He has been active with ASEE and educational research for over 10 years. He is particularly interested in enhancing critical thinking skills among civil engineering students through various educational approaches. His research interests include water and wastewater treatment, desalination, and algal biofuels.

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Integrating Writing to Teach Engineered Environmental Systems Design – Learning and Teaching Experiences

Abstract

Writing in engineering courses provides a mechanism for processing scientific information related to an engineering issue or problem 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. On the other hand, the Accreditation Board for Engineering and Technology (ABET) has stipulated the engineering education outcomes 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. These outcomes are hard to achieve in a traditional compartmentalized engineering curriculum. These intangible ABET outcomes can be better accomplished by providing writing assignments to engineering students.

In our civil engineering senior design elective course, CE 4883-6883 Engineered Environmental Systems at Mississippi State University, we have incorporated various types of writing exercises such as informal writing, free writing, exploratory writing, formal writing (project report), and reflective writing to enhance student learning of the subject matter. Informal writing involved a critical review of different stormwater pollution management issues and current best management practices and a comparison of the alternatives. Free writing was given in class to promote free thinking and thinking through writing. Exploratory writing exercise involved a topical discussion of stormwater treatment process. A formal writing exercise was given in the form of a stormwater pollution prevention plan (SWPPP) assignment which included a peer–review session prior to final grading. A reflective writing exercise was included to summarize learning experiences through classroom and writing activities throughout the semester to identify areas of strengths and weaknesses and accomplishments and pitfalls and areas/topics for future development.

Student learning experiences and the effectiveness of writing exercises were discussed. The benefits of writing exercises were evaluated through the ABET outcomes and a survey and evaluation of students' performance throughout the semester. Results from this preliminary study suggested the need for more structured writing assignments and detailed analysis and assessment /evaluation process for identifying the effectiveness of writing exercises for developing critical thinking skills and for achieving ABET outcomes.

Keywords

Engineering education, environmental engineering, engineering design, student learning, critical thinking and writing to learn

Introduction

The ability to write is often considered merely 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 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 through traditional assignments and exercises. However, objectives (f) through (j) are not easily accomplished. These are intangible outcomes which need specific and tailored exercises to be effective[1]. 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 a tangible and an intangible 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 reflective and self-regulatory judgment exemplified by critical thinking[2-4].

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[5]. 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[6]: (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 (see Table 1). Because writing can facilitate a process for critical thinking and a means for effective communication, writing in an engineering curriculum can provide an appropriate mechanism for achieving the aforementioned ABET outcomes.

Writing exercises

Writing assignments have been used in many engineering courses to improve student learning experiences through active learning and problem-based learning. This is because writing is considered an essential skill for technical specialists and managers, senior engineers who deal

with other professionals such as lawyers and planners, in situations dealing with disputes, and in the process of continuous learning (life-long) [7-10]. Therefore, the other specific objectives of this education research activity are[11]:

- To help students recognize the importance of writing in the classroom and workplace.
- To promote a desire among students to correct their writing deficiencies and to improve their professional writing skills.
- To use writing as a way for students to learn and clarify thinking.
- To establish sufficient opportunities to practice and develop their writing skills.
- To give appropriate advice, criticism, and correction to promote improvement through revision.

Writing assignments were used to create a practical context that deepens their understanding and comprehension of the content area[3-7, 11-13]. 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 within the course content. This is a classroom exercise.

Exploratory writing – students were asked to prepare a short essay of 500-1000 words on a topic of their interest within the course content related to stormwater management and treatment alternatives.

Informal writing – A critical review of the existing storm water management practices and alternative design 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 areas for improvement (500-1000 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

ABET Criterion 3 Outcomes	**Writing Exercise**	**Bean critical thinking task**
(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	**SWPPP** **Reflective Writing**	**1, 2**
(g) an ability to communicate effectively	**SWPPP, Critical Review, Exploratory Writing**	**1, 2**
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	**Critical review** **Reflective Writing**	**2**
(i) a recognition of the need for, and an ability to engage in life-long learning	**Free Write** **Exploratory Writing**	**2** **2**
(j) a knowledge of contemporary issues	**Critical review** **Reflective Writing**	**2**
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	**SWPPP** **Critical Review**	**1, 2**

Summary of student experiences and (self) evaluations

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).

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.”

For the critical review writing exercise, student experiences were gathered through their opinions in the form of a short summary consisting less than 100 words. 28 responses were received for this exercise. Table 2 lists a summary of responses and remarks. It can be noted that more than 50% of the students 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 (although it was intentional) seemed to cause some confusion and increase complexity of the writing exercise.

Table 2. Summarized student responses to critical review writing exercise

Learning experience	**Number of participants**	**Remarks**
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, realized to become a good writer
Not interested	1 (3.6%)	Busy schedule, know enough about writing

When asked, 70% of the students reported that they had writing assignments in other engineering courses other than English and technical writing courses. Some general questions about the writing assignments in relation to the course content were asked. The results are as follows.

- 72% of the students agreed or strongly agreed that these assignments improved their learning experience
- 85% of the students agreed or strongly agreed that these assignments instilled interest in the subject matter
- 60% of the students agreed or strongly agreed that total number of assignments (five) was adequate
- 76% of the students agreed or strongly agreed that these assignments were appropriate for the course
- 88% of the students opined that three to five writing assignments would be appropriate for the course.

Table 3. Responses to questions related to writing assignments and their appropriateness to the course content

Course related questions on writing exercises	**(%) Strongly Disagree**	**(%) Disagree**	**(%) Neither Agree nor Disagree**	**(%) Agree**	**(%) Strongly Agree**	**Average (1-5)**	**Std. Dev**	**(%) Agree or Strongly Agree**	**(%) Disagree or Strongly Disagree**
Improved learning experience	3	0	15	49	33	4.1	0.86	82	3
Instilled interest in the subject matter	3	0	12	58	27	4.1	0.83	85	3
Number of assignments was adequate	3	9	27	42	18	3.6	0.99	60	12
Writing assignments were appropriate for the course	3	0	21	52	24	4.0	0.85	76	3
Reasonable number of writing assignments (1-5)	3 (1)	9 (2)	49 (3)	27 (4)	12 (5)	3.3	0.92	88 (3-5)	12 (<3)

Students' responses on the ability of writing assignments to provide opportunities for developing critical thinking, creative thinking and reflective thinking (Figure 1) all followed a similar pattern in that 52%-61% of the students agreed that the writing assignments were helpful to develop these skills. 6%-18% of the students neither agreed nor disagreed while 24%-30% of the students strongly agreed to this effect.

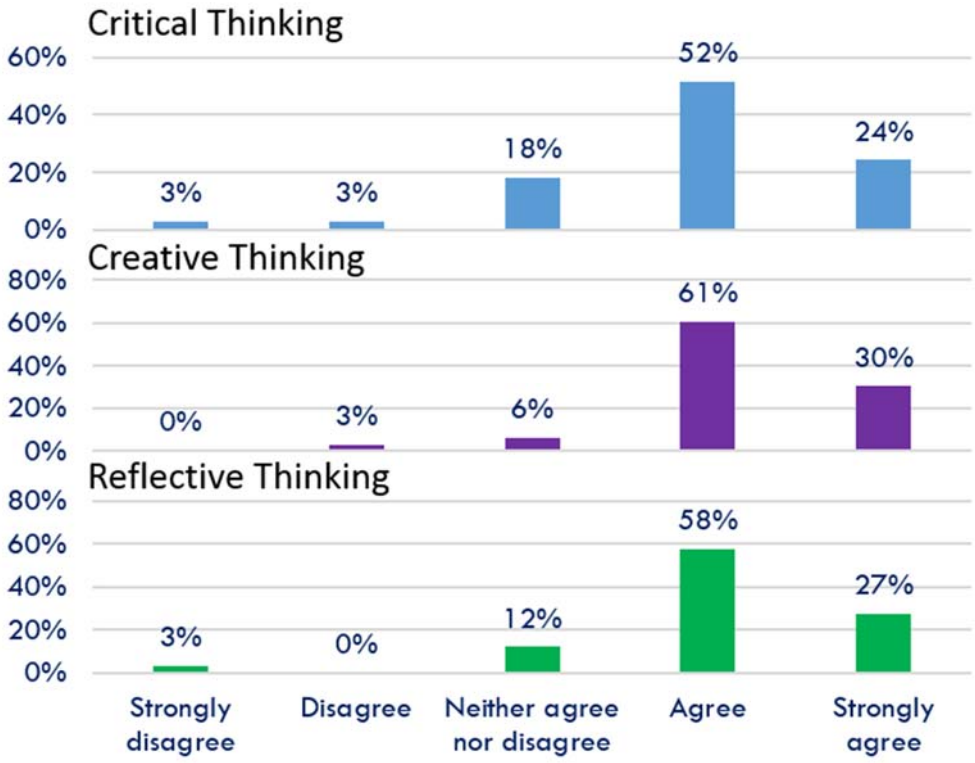

Figure 1. Responses to questions related to writing assignments and their appropriateness to the course content

Summary of students' responses on intangible ABET outcomes (f) through (j) are shown in Figure 2.

- 61% of the students agreed or strongly agreed that writing assignments have developed an understanding of professional and ethical responsibility
- 67% of the students agreed or strongly agreed that writing assignments have improved the ability to communicate effectively
- 64% of the students agreed or strongly agreed that writing assignments have increased the awareness of the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- 70% of the students agreed or strongly agreed that writing assignments have developed an understanding of need for life-long learning

- 76% of the students agreed or strongly agreed that writing assignments helped improve knowledge of contemporary issues in the subject area
- 66% of the students agreed or strongly agreed that writing assignments have provided opportunities to use techniques, skills and modern engineering tools

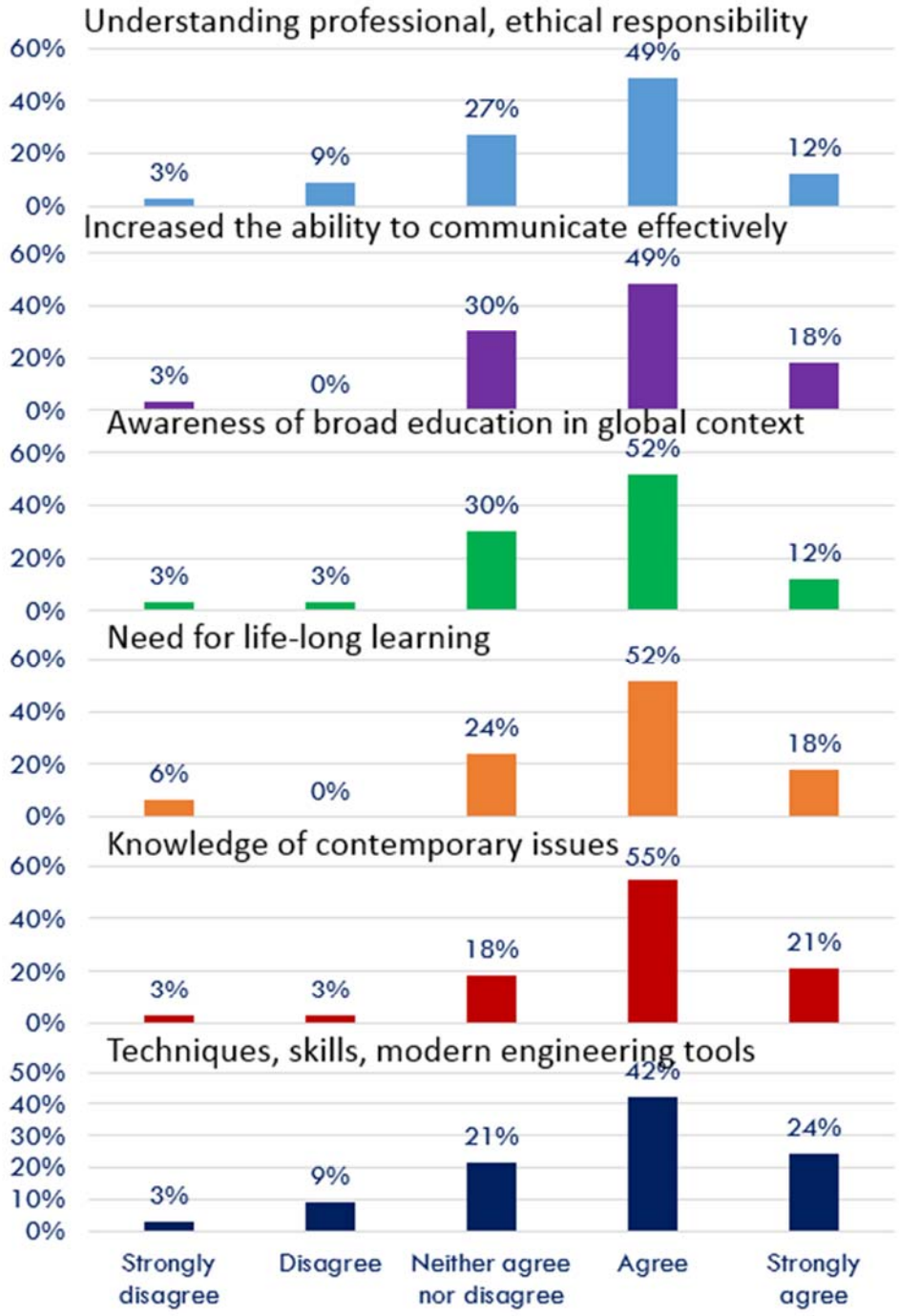

Figure 2. Responses to questions related to writing assignments and their relation to ABET outcomes

From Figures 1 and 2, it can be noted that up to 30% of students have expressed a neutral opinion on the effectiveness writing exercises. It may be because, in general, engineering programs and courses do not emphasize on writing assignments as a way of promoting deeper learning of the course content. The students (as well as many instructors) carry a perspective that engineers do not need to write and therefore they do not need good writing skills. Other than English composition and technical writing courses offered in freshmen to sophomore/junior levels in the curriculum, most of the other engineering courses do not incorporate writing exercises. Therefore students may find themselves out of place when they have to work on a writing exercise that is not "typical" of a subject-oriented engineering design elective course. This should be considered a critical outcome. The instructor has strived to help students realize the importance of writing by providing examples from his own professional experience and others. Students were reminded in a number of occasions that they are nearing graduation and need skills such as these to communicate effectively with their clients and employers.

Higher levels of learning

Students were asked to select the levels of learning which were required or seemed important in completing these writing assignments. Bloom's taxonomy was used to gather responses which are shown in Figure 3 and Figure 4. It can be noted that a high percentage of students mentioned that knowledge (88%) acquisition was the major step followed by comprehension (76%), application (82%) of the knowledge gained, and analysis (73%) of various options and synthesis of solutions (58%) and evaluation of the design (79%). Interestingly, synthesis was not considered an important type of learning in this class which is a surprising outcome from this survey. But from the definitions of these nouns (see below), it is clear that students had (or have exercised) performed a little low at this level. When asked to respond on the individual writing assignments, synthesis still lags behind other learning levels.

An attempt was made to gather student responses related to the five levels of the affective domain of the bloom's taxonomy, definitions of which are shown below[14]. A summary of responses is shown in Figure 5. These responses are somewhat intriguing in that "organization" received the highest score. This may possibly mean that students took the word "organization" for "arranging" the information gathered to complete these exercises. An interesting observation was that "receiving" was reported to be of low importance (24%), for which, there is no clear explanation at this time.

Definitions

Knowledge: the recall of specific items
Comprehension: can recall, but can do a little more (e.g. paraphrase, define, discuss to some extent)
Application: all of the above, but can take information of an abstract nature and use it in concrete situations
Analysis: can break down a communication into its constituent parts, revealing the relationships among them
Synthesis: can pull together many disorganized elements or parts so as to form a whole
Evaluation: makes judgements about the value of materials or methods

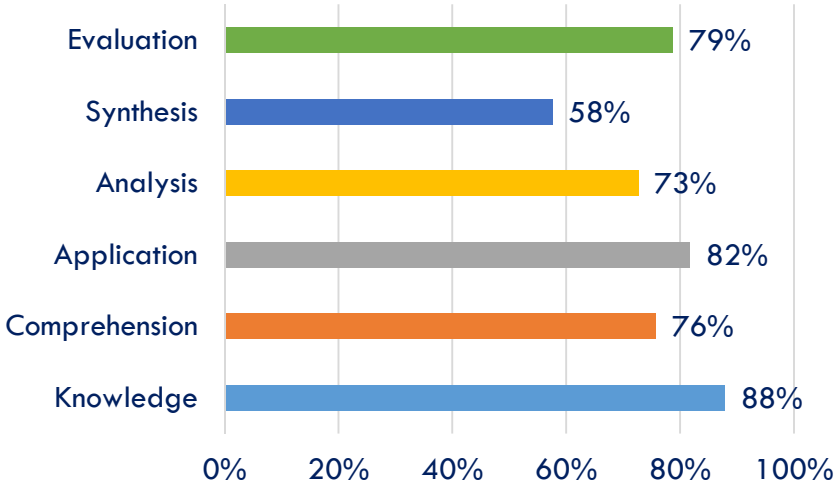

Figure 3. Student responses to the levels of learning in the writing assignments (overall)

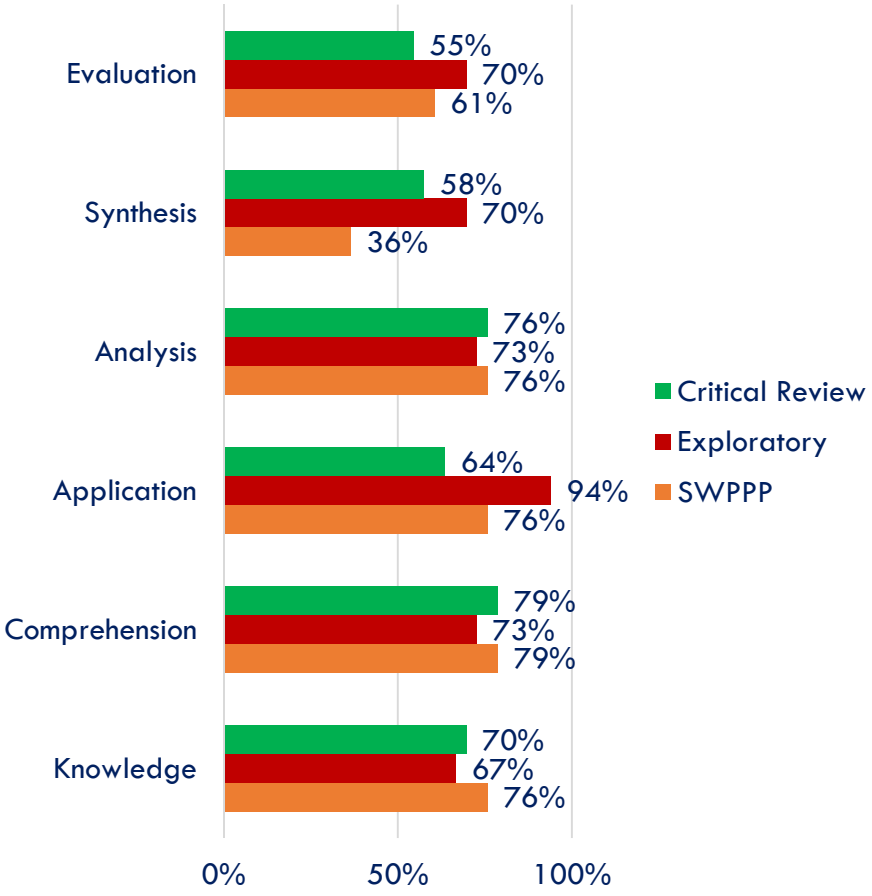

Figure 4. Students' responses to Bloom's Taxonomy - Levels of learning through writing exercises

Receiving: is willing to notice a particular phenomenon
Responding: makes response, at first with compliance, later willingly and with satisfaction
Valuing: accepts worth of a thing
Organization: organizes values; determines interrelationships; adapts behavior to value system
Characterization: generalizes certain values into controlling tendencies; emphasis on internal consistency; later integrates

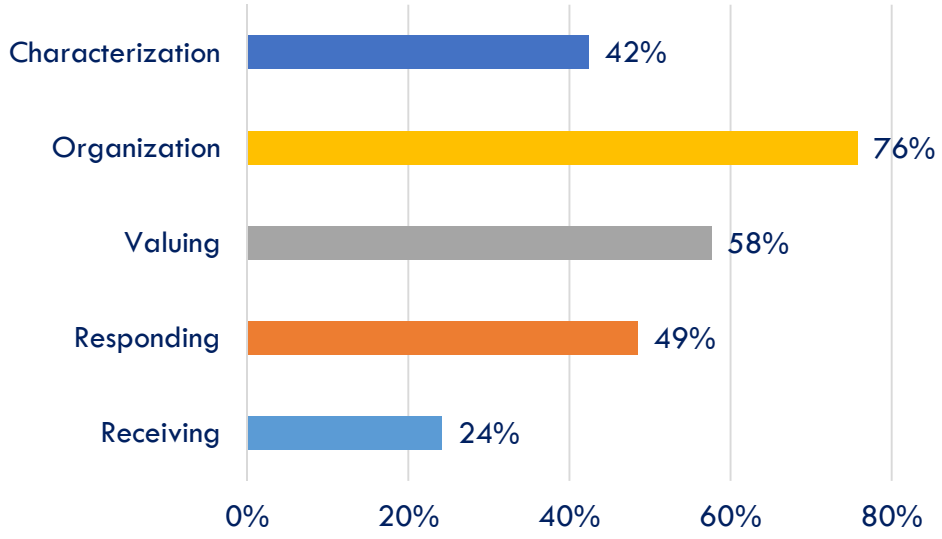

Figure 5. Students' responses to five levels of the affective domain in Bloom's Taxonomy related to learning through writing exercises

Instructor's perspectives

The instructor's objectives for the writing assignments/exercises are summarized in Figure 6. Table 4 shows the relevant objectives for each of the writing assignments/exercises.

Instructor's writing objectives:

1. To help students recognize the importance of writing for the course and profession.
2. To promote a desire to correct their writing deficiencies and to improve professional writing skills.
3. To use writing as a tool to learn and clarify thinking and promote critical thinking.
4. To establish sufficient opportunities to practice and develop writing skills.
5. To give appropriate advice, criticism, and correction to promote improvement through revision.

Table 4. Specific objectives for the writing assignments/exercises

Writing Activity	**Writing Objectives**	**Educational Objectives**
Free writing	1	Deeper thinking
Exploratory Writing	1, 2, 3	Connect theory to practice
Critical Review	1, 2, 3, 4	Conceptual understanding

		Critical thinking Engineering judgement
SWPPP (with peer review)	1, 2, 3, 4, 5	Professional writing Engineering design Critical thinking
Reflective Writing (with peer review)	1, 2, 3, 5	Lifelong learning Self-assessment

The goal of the "Free Writing" exercise was to introduce students to writing exercises in the course and to break the barriers or to overcome the resistance to write in the course. When the expectations for writing were low in terms of correctness for grammar and sentence formation, the students took the opportunity to explore their writing exercise as a tool to clarify thinking. As it is reflected in the student opinions (see above).

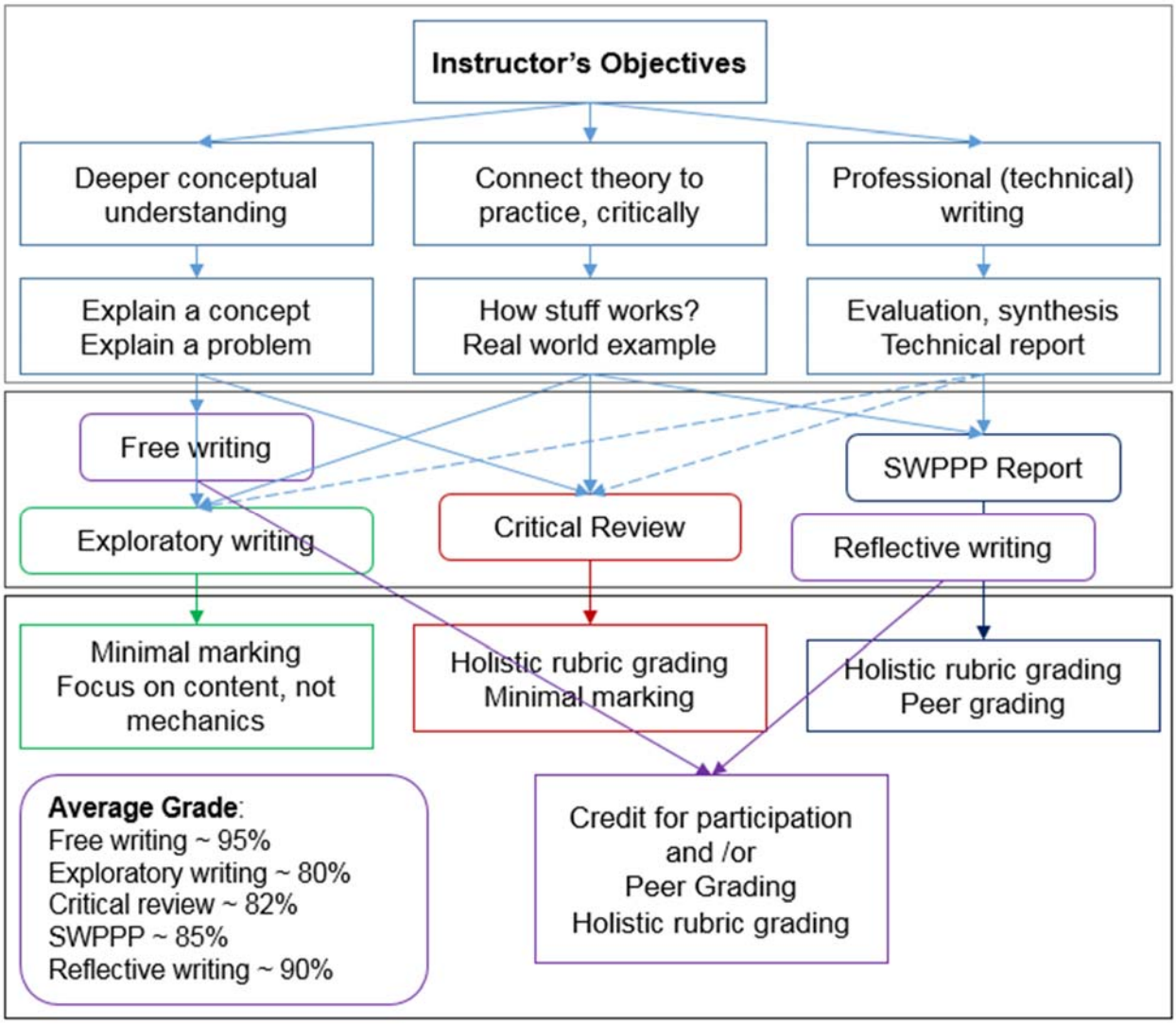

Figure 6. Instructor's objectives, connection to assignments and grading methods and average student grades

The performance of students has improved significantly from one exercise to other with continuous feedback. From exploratory writing through critical review assignment and SWPPP exercises, the student thinking skills have improved significantly. The quality of submissions increased and the level of depth and discussion improved. Providing a series of simple exercises has enabled students to develop a technical/profession rigor for writing and writing- to-communicate the subject matter. For example, as shown in Figure 6, different methods of grading were considered such as “credit for participation”, “minimal marking”, “and “holistic grading”, and “peer grading”. Where possible “credit for participation” given to encourage students to write. For example, first exercise “Free writing” aiming to overcome potential barriers for writing, was graded by “credit for participation”. Similarly, last assignment “reflective writing” aiming to provide the skills for life-long learning and self-assessment was graded by both “holistic grading”, and “peer grading”. Second writing exercise “Exploratory Writing” received an overall low average score mainly due to grammar-related and sentence formation related issues along with some technical inaccuracies.

ABET outcomes have been addressed to some extent in these exercises because the assignments especially critical review and SWPPP were designed to allow students learn from the knowledgebase and devise their own design. Students would encounter numerous opportunities that allow them to accomplish these intangible outcomes.

Peer-Review Workshops

One of the effective writing strategies suggested by Sharp et al includes peer-editing[15]. We have conducted two peer-review sessions to provide feedback on SWPPP and reflective writing exercises. The instructor received support from Maroon Institute for Writing Excellence (MIWE) at the university to conduct peer-review workshops (15-20 minute presentation/ discussion followed by student exercise on peer-review evaluation. Evaluation forms were provided to guide the review process for SWPPP and reflective writing exercises separately which are shown in Table 5. The feedback from this exercise was used to finalize the writing assignments.

Table 5. Peer-review forms for SWPPP and Reflective Writing exercises

SWPPP Writing Workshop: Peer-Review Form

1. Is the paper’s content understandable and convincing? If not, what is confusing or lacking?
2. What are the paper’s major strengths and/or weaknesses?
3. Does the introduction clearly indicate the subject and scope of the paper?
4. How detailed is the paper? Are these places where additional details would be helpful?
5. If there is a recommendation, is it clearly and explicitly stated? Are there any ways it could be misunderstood?
6. Are the consulted sources credible?
7. Are the graphics clear and adequately explained in the text?
8. Note any grammatical issues. What seems to be the most problematic grammar/writing problem?

Reflective Writing Workshop: Peer-Review Form

1. Is the paper's content understandable and convincing? If not, what is confusing or lacking?
2. What are the paper's major strengths and/or weaknesses?
3. Does the introduction clearly indicate the subject and scope of the paper?
4. How detailed is the paper? Are these places where additional details would be helpful?
5. What specific aspects of the coursework does the author reflect on? Why are these aspects focused on?
6. How does the author explain his/her progress with learning the tools covered in the course?
7. Does the author reflect on how the content learned might be used in practical applications?
8. Does the author evaluate his/her own assumptions about the course and discuss how/whether they have changed?
9. Note any grammatical issues. What seems to be the most problematic grammar/writing problem?

Figure 7 shows the involvement of civil and environmental engineering students during the peer-review exercise.

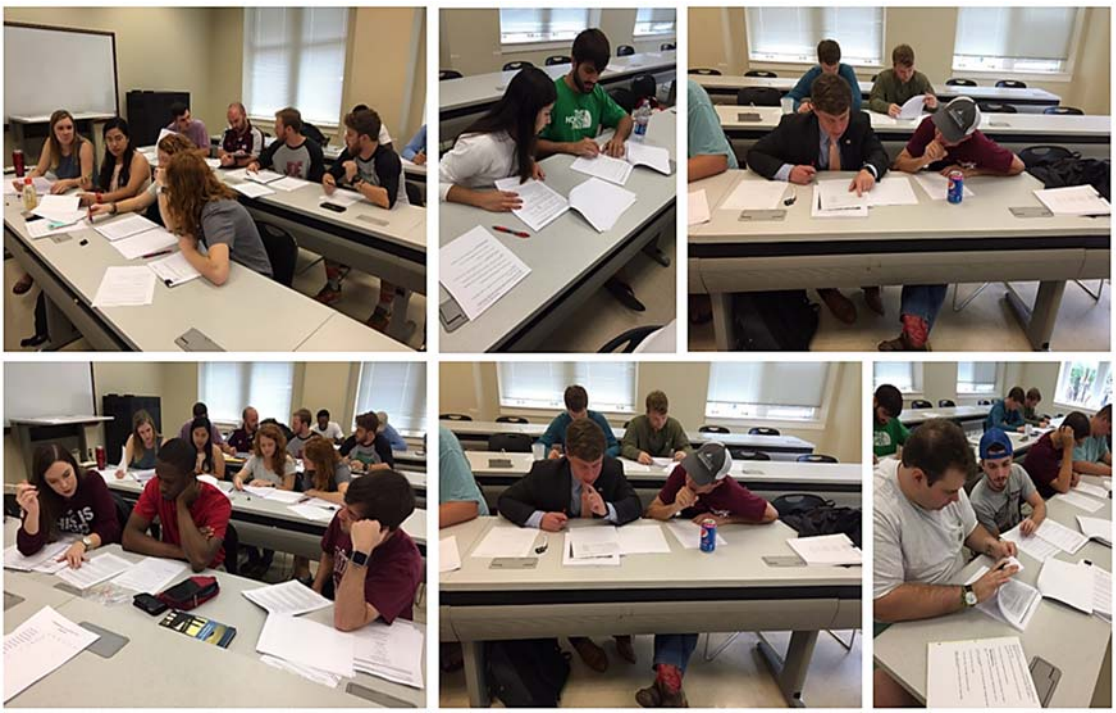

Figure 7. Civil engineering students performing peer-review evaluation on SWPPP report

Reflective writing exercise was given to provide the students with an opportunity to critically evaluate their learning experiences to assess what had worked and what had not, and areas or topics for improvement. Peer-review workshop for the reflective writing exercise was provided to allow appraisal and criticism from peers. The goal for this workshop was to provide feedback from others about their learning process.

MIWE is interested in learning more about the students learning experiences through writing assignments in this course. A group of students were selected randomly to participate in a formal review session to provide feedback on the effectiveness of writing activities in this course. This meeting will be held towards the end of this semester at the library. MIWE hopes to gather this information for other courses as well to promote writing across curriculum to achieve higher student success in various disciplines.

Conclusions

The importance of integrating writing assignments to teach environmental engineering concepts from the perspective of developing critical thinking skills and meeting 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 more structured guidelines on format and content requirements and scope definitions for individual exercises and a structured assessment and evaluation process. These components provide opportunities for continuous improvement and thus learning and teaching experiences in the years to come.

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