Freshman Entrepreneurship Student Critical Thinking Enhancement through Paired Engineering and English Composition Courses

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Abstract

Critical thinking consists of "reasonable reflective thinking that is focused on deciding what to believe or do. More precisely, it is assessing the authenticity, accuracy, and/or worth of knowledge claims and arguments" (Shoop 2003). Learning communities have been one of the most important educational reforms to come about and are particularly successful for freshman students. Clustering and pairing of classes are a type of learning community where there is a cross-fertilization of ideas and assignments that helps to show students how material is applied in a variety of contexts. Course pairing is particularly appropriate when a "skills" course (such as English composition) is paired with a "content" course (such as Engineering Entrepreneurship). This project placed the students in courses in the student's freshman year to improve critical thinking skills as they apply to entrepreneurship. Experiences and assessment of the learning community will be given.

Introduction

This paper reports on a study done to determine the critical thinking skills of freshman entrepreneurship engineering students as measured by assessing assignments written in response to a cooperative in-class activity, attitude surveys, and academic credentials. The class, a freshman-level, one-hour course (Introduction to Engineering), has been taught by the author, Dr. Karen High (an engineer) for eight years and is a fall class. The class meets for fifteen hours during the semester and covers six main areas: academic success; professional success; engineering information; engineering design and problem solving; societal issues of engineers; and personal development. Essentially, this course addresses "professional skills" as defined by ABET criteria. This paper looks at two sections of this course, one from 2006 and one from 2007.

Over 100 years ago, one of the earliest American educational theorists, John Dewey, expressed in *My Pedagogic Creed* that "much of present education fails because it neglects this fundamental principle of the school as a form of community life." The establishment of "learning communities," has been one of the most one important educational reforms to come about based on Dewey's challenges. Learning communities have been shown to be particularly successful for freshman students. Clustering and pairing of classes help form a type of learning community where there is a cross-fertilization of ideas and assignments that helps to show students how material is applied in a variety of contexts. The integration of material across courses allows students to apply skills as they learn them.

To achieve improved critical thinking for freshman students, this project:

(1) Placed the students in paired English composition and Engineering courses in the fall semester of the student's freshman year.
(2) Provided multiple critical thinking assignments to allow students to improve their skills.
(3) Measured improvements in critical thinking skills as students progressed through the semester.
(4) Provided an environment of learning that enhanced the students' freshman experience.

The cooperative in-class activity, the "Airplane Design Challenge," asks students to jointly find solutions to the problem of designing an airplane with limited materials and production challenges in order to learn the essential notions in engineering of process and product design. The written assignment asks students to complete a reflective assignment in which they consider their impressions from the activity, how well their group functioned together, describe their group's product and process design, provide definitions of product and process design, and draw conclusions about what this exercise tells them about what engineering is and what an engineer does.

A perfect setting for practicing and assessing critical thinking skills, the "Airplane Design Challenge" was modified in the fall 2006 and fall 2007 semester to include explicit questions about the students' perspective on the activity:

- Was the Airplane Design Challenge a good way to learn to understand the similarities and differences between product and process design?
- What is the difference between product and process design?

These questions acted as the central concept students could develop through the reflections and definitions traditionally required of the assignment. Dr. High, Dr. Damron (an English faculty member) and another English faculty member assessed the students for critical thinking and writing ability using university-wide assessment rubrics.

Background

Increasing attention has been given to the development of what have been called the "soft" skills in engineering, which the recent accreditation criteria of ABET (Accreditation Board of Engineering and Technology) call "professional" skills. These professional skills highlight recognition in the field of engineering that in order to compete in a global context, students must be prepared to communicate, work in teams, understand the impact of various decision-making processes, and engage in lifelong learning. Shuman, Besterfield-Sacre, and McGourty (2005) outline the elements of these professional skills and categorize them as either "process" or "awareness" skills and argue that these skills can be taught and assessed. The challenge then becomes how to teach these skills. Smith, Sheppard, Johnson, and Johnson (2005) discuss the effectiveness of "pedagogies of engagement" which include problem-based learning, team projects, and cooperative learning classroom practices which can aid engineering educators in developing learning environments that are in keeping with current approaches to teaching, and which aid in the outcomes for the training of professional skills as outlined by ABET.

Of particular interest to this study are two categories of what Shuman et al. (2005) call lifelong learning skills: the ability to demonstrate effective writing and critical thinking skills. Critical thinking consists of "reasonable reflective thinking that is focused on deciding what to believe or do. More precisely, it is assessing the authenticity, accuracy, and/or worth of knowledge claims and arguments. It requires careful, precise, persistent and objective analysis of any knowledge claim or belief to judge its validity and/or worth" (Shoop 2003). Critical thinking is grounded in engagement with problems. In fact, for Dewey (1916), from whose work problem-based approaches to teaching are drawn, engagement has to do with wrestling with the context and conditions of the problem. So deciding what to believe or do comes with a process that includes analyzing and judging assumptions as well as exploring alternative ways of thinking about a topic. Bean (2001) proposes that the connection between writing and critical thinking is that "writing is both a process of doing critical thinking and a product communicating the results of critical thinking." As such, critical thinking and writing go hand in hand.

For the engineering educator, implementing and integrating the professional, institutional, and pedagogical goals and expectations into a course is complex and becomes much more so when developing and implementing curricula for freshman students. These students are not always comfortable with problem-posing situations, and as the tasks increase in complexity, so does the difficulty in thinking and writing about those tasks (Bean 2001). Bean suggests that teaching the process, which involves engaging, developing, complicating, and clarifying ideas through writing, is slow and developmental. In order to help students through this process, Bean also suggests that the teaching should create "cognitive dissonance" or use "decentering" exercises that challenge students to look at other perspectives. In addition, knowledge should be presented as dialogic; and we should create opportunities for active problem-solving that involve dialogue and writing.

This paper reports on a study conducted in an Introduction to Engineering Course in which the students participated in the Airplane Design Challenge and subsequently wrote a formal assignment. Students were required to discuss this experience and were asked to draw larger conclusions about a key engineering concept. The papers were then assessed for writing and critical thinking skills using rubrics developed for Oklahoma State University.

The purpose of the assessment was to address the main question of this paper as presented in the title—to what extent are freshmen engineering students able to think and write critically? In addition, the results of this study are expected to contribute to the benchmarking process for the rubrics at Oklahoma State University.

The Introduction to Engineering Course

The major goal of this course is to increase retention of freshman students by introducing the students to engineering concepts and experiences. Another major goal of the course is to address the professional skills of ABET. There are twenty-five sections of the class taught in the college, with each section typically having twenty-one students. Two of these sections were populated with engineering entrepreneurship students (with overflow enrollment due to demand). One section of engineering entrepreneurship was offered in fall 2007.

The three sections (two in 2006, one in 2007) identified for the study consisted of freshmen engineering majors from across the College of Engineering. The class met for fifteen hours during the semester, plus extra time for meetings with success coaches/peer mentors and additional speakers. The six main areas covered in the class are:

- Academic Success—study skills, time management, finding help for classroom material, test-taking skills, and college survival skills
- Professional Success—career-planning and effective presentations
- Engineering Information—career and advisement information and research presentations/laboratory tours
- Engineering Design and Problem Solving—creativity, effective teams, brainstorming, process design, and product design
- Societal Issues of Engineers—ethics, diversity/international issues, environmental issues/sustainability, medicine and bioengineering
- Personal Development—stress management and other wellness issues

This course is a particularly good class to do problem-based, cooperative activities because it addresses the goal of giving students engineering experiences that truly engage them. Adding the Airplane Design Challenge experience to the class fits these goals with the added potential of acting as a means of retaining students, a college and university-level goal.

The Airplane Design Challenge

The Airplane Design Challenge was developed for this course because it is problem-based, gives students a chance at cooperative learning, involves dialogic opportunities for thinking, makes students consider other perspectives, builds team learning, promotes student engagement, simulates how the design process/product works and helps make connections to what engineering is all about.

The Airplane Design Challenge is conducted in the fifth week of the semester so that the students have had a chance to get to know each other, making teamwork easier while engaging them early enough to use these experiences in later semester activities. The activity is done in a fifty-minute class period. The students are first placed in multidisciplinary teams of three to four and asked to create a name for the team, after which they receive a handout containing the materials and instructions for the challenge (Figure 1).

Figure 1 – Airplane Challenge

Product/Process Airplane Design Challenge

Given the following items:

Toothpicks	Ziploc bag
Rubber bands	Lunch bags
Paper clips	Tootsie rolls
Post it notes	Lifesavers

Gum

Design an airplane using materials given (10 minutes)

Place prototype at front of classroom on paper along with group name

Design a process/method to manufacture the airplanes (5 minutes)

Be aware that I will provide calamities/upsets

Build airplanes (10 minutes)

Deliver your airplanes in one (or more) lunch bag to the front of the classroom next to the prototype

Group name must be on lunch bag

Evaluate products (5 minutes)

Rank (individually) the group designs for those that meet specifications (looks like an airplane)

Next week I will tell which group "won"

Equal weights to product design/process design.

Keep track of activities/thoughts in your lab book!!!!!!!

Teams take toothpicks, rubber bands, paper clips, tootsie rolls, post it notes, lifesavers and gum and design a prototype airplane (it doesn't have to fly). The team then designs a process/method to manufacture airplanes with the understanding that process calamities and upsets might occur during this phase (i.e., a student might be made to simulate a work-related accident by not allowing them to use an arm or supply chain issues are simulated by removing some of their tootsie rolls or power outages simulated by shutting of the lights and not allowing anyone to work). The teams then build as many airplanes as they can in ten minutes and deliver them in a shipping container (lunch bag). Students individually rank the group designs for those planes that meet specifications (looks like an airplane). The team receiving the most points from the ranking wins the product design contest and the team producing the most airplanes wins the process design contest. Students keep track of details in a lab notebook.

The Writing Assignment

This assignment was designed against the backdrop of assessment work being done at Oklahoma State University. The Critical Thinking Assessment Committee has suggested that freshman-level courses lack explicit requirements for or assessment of critical thinking. The components of the assignment were developed to specifically address university-developed writing and critical thinking rubrics, making the resulting papers suitable for rubric assessment and development. This assignment afforded a writing experience for the students within their own disciplinary work, unlike typical writing experiences in freshman composition, by writing about and assessing an in-class engineering experience.

The students were also given a copy of the writing assignment (Figure 2) at the beginning of the hour so that they knew what was expected of them. By having the writing assignment ahead of time, they were provided with a focus that would provide for meaningful entries in their lab books.

Figure 2 – Writing Assignment

Product/Process Design Homework

Due Week of October 2, 2006

30 points

Prepare a 2-3 page double spaced 12 point font Microsoft Word document (paper/essay) that addresses the following. Be very clear in your document about which of the items you are addressing. Remember that all course documents are on Blackboard. I will be adding more resources on Blackboard to help you understand product and process design.

1) Your name, your group name, and members.

2) Was the "airplane design challenge" a good way to learn to understand the similarities and differences between product and process design? This is the main theme of your paper.

3) Use documents provided in class, on Blackboard, as well as at least one other resource that you find to provide definitions and to support your claims for #2 above. Provide references to your sources.

4) Discuss your group's product and process design.

5) Describe how your group functioned together. Were they effective?

6) Conclude by summarizing your key points (to support #2 mostly but others for #4 and #5 as needed) and describing how important product and process design is in engineering.

7) Provide a bibliography of your sources.

Students were provided with design resources (Lumsdaine and Lumsdaine 1999; Nazemetz 2004; Cussler and Moggridge 2001; Jensen 2004) that assisted student learning of engineering product and process design concepts. Students were required to find outside sources to use as evidence to support their claims about the Airplane Design Challenge and its ability to help them understand the difference between product and process design (see Table 2). In addition, this task helps the students learn how to do research of relevant literature.

Because group work is a very important part of engineering, the students were asked to consider how their groups functioned together. The assignment was also written to get the students to realize that the exercise itself required critical thinking. The exercise made them question their own assumptions about design and engineering. It required them to consider alternatives in both the product and process design phases.

Demographics of Students

All students who participated in the study were engineering students from across the college. Demographic distinctions between sections are shown in Figure 3:

Figure 3-Demographics of Students Fall 2006

Section A:

23 Students (3 males did not complete the assignment) 16 male and 7 female

Male and Female students in an Entrepreneurship Engineering section

One of the first sections of Engineering 1111 to fill up (cap usually is 21 students)

Section B:

24 Students (2 males did not complete the assignment) 19 male and 5 female

Male and Female students in an Entrepreneurship Engineering section

Section opened up during the middle of summer enrollment after Section A filled

It was expected that Section A would perform very well because of their desire to enroll early and be in an engineering entrepreneurship section, as well as from observations during the first five weeks. Students interested in entrepreneurship tend to be ambitious and internally motivated. Section B was expected to perform lower on the assignment. These students had not been very engaged in the first weeks of the semester and appeared to lack motivation. They had already established a pattern of complaining about any amount of work.

Assessment

Because one of the goals of the this study was to contribute to the process of developing the assessment instruments for the university assessment committee, the writing assignment and assessment measures were designed to complement this process. At the current time, the committee is establishing a benchmark

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of students that evaluates current abilities towards critical thinking. Once this benchmarking has occurred, the appropriate interventions for improving the critical thinking ability of the students will be determined. The fact that the products resulting from the assignment were in written form generated curiosity about using both the writing and critical thinking rubrics and the relationship between the two.

To obtain the results for the study, three faculty members were selected to do the rating using both rubrics. Two faculty members from the English department are heavily involved in teaching writing on campus and have extensive experience with writing skills: the director of the Freshman Composition program and the Director of the university Writing Center. The third rater was from the College of Engineering and an instructor of the course profiled in this study. The rubrics are explained in Figure 4.

Figure 4-The Rubric Criteria

The Writing Rubric uses the following three criteria:

1. Content
2. Organization
3. Style and Mechanics

The Critical Thinking Rubric uses the following seven characteristics:

1 – 4: Essential Characteristics

1. Identification and/or summary of the problem/question at issue
2. Presentation of the STUDENT'S OWN perspective and position as it is important to the analysis of the issue.
3. Assessment and appropriate use of supporting data/evidence.
4. Discussion of conclusions, implications and consequences.

5-7: Optional Characteristics (evaluate where appropriate)

5. Consideration of OTHER salient perspectives and positions that are important to the analysis of the issue.
6. Assessment of the key assumptions and the validity of the supporting/background information.
7. Consideration of the influence of the context on the issue (including where appropriate, cultural, social, economic, technological, ethical, political, or personal context)

The papers were ranked on a one-to-five scale for each, with one low and five high. The students' work was ranked for the three writing criteria with an overall score and for the seven critical thinking criteria with an overall score. The three faculty members were provided with anonymous copies of the student work. Each professor rated the papers with the one-to-five values for each component of the two rubrics. This rating was completed after the end of the semester and after course grades were assigned by the author. Inter-rater reliability was determined for overall ratings and ratings on subsection as indicated in Table 1.

Table 1-Interrater Reliability

	W1*	W2	W3	WO	C1	C2	C3	C4	C5	C6	C7	CO
R1R2**	0.189	0.367	0.189	0.204	0.100	0.157	0.550	0.475	-0.038	0.274	0.110	0.365
R1R3	0.308	0.275	0.297	0.297	-0.102	0.252	0.418	0.125	0.191	0.205	0.187	0.332
R2R3	0.436	0.172	0.172	0.172	0.048	-0.110	0.205	0.122	0.073	0.151	-0.019	0.087
OA	0.53	0.49	0.34	0.49	0.22	0.25	0.60	0.47	0.22	0.34	0.26	0.49

*W1 corresponds to writing criteria 1, etc. WO is overall writing score, C1 corresponds to critical thinking criteria 1, etc. CO is the overall critical thinking score.

**R1R2 is Rater one compared to Rater two, etc. and OA is the overall interrater reliability.

Reliability was calculated using a formula, which took the average r correlations, converted to Z scores to allow for r distortion. Table 1 shows that the reliability was quite low among raters across the board. A score of 0.75 is on the low end for non-normed situations; ideally, it is desired to be closer to 0.9. Raters tended to be more internally consistent within and across rubrics. Part of the reason for the lack of consistency among raters could be the fact that not all raters were familiar with both rubrics prior to participating in this study and time constraints prevented a proper norming session among raters prior to rating. There may also be a challenge with the validity and reliability of the rubric itself. Additionally, engineering faculty may be looking for different things than English faculty as they review the artifacts.

Results

Table 2 contains the results of the ratings by section and by criteria on both rubrics for fall 2006.

Table 2– Assessment Results for Fall 2006

	W1**	W2	W3	WO	C1	C2	C3	C4	C5	C6	C7	CO
Section												
A	2.88	2.81	2.70	2.77	2.95	3.21	2.89*	2.74	2.12	2.54*	2.75*	2.84
Section												
B	2.82	2.65	2.79	2.77	2.95	3.19	2.60*	2.54	2.11	2.21*	2.26*	2.81

** W1 corresponds to writing criteria 1, etc. WO is overall writing score, C1 corresponds to critical thinking criteria 1, etc. CO is the overall critical thinking score.

* These numbers show where a paired t-test between the two sections showed that there was a significant difference at $p<0.05$, a statistically significant difference at the 95% confidence level.

These scores are the average of the three rater's scores. The criteria that the students performed the best in was Criteria C2, "presentation of the students' own perspective" which may be an outcome from the assignment specifics that asked for their perspective. The lowest score was seen for Criteria C5, "consideration of other perspectives" (an optional criteria used by the raters). The assignment, however, did not specifically ask for the students to do this. Freshman students may not have the maturity to consider this addition.

Upon comparing the sections, Section A was able to consider the influence of the context of the issue (Criteria C7-optional) and Section B performed the worst. In both cases these were very large differences. Section B appeared to have challenges with use of supporting data (C3), assessment of assumptions (C6), and influence of context (C7). The performance of the sections on the writing and critical assessment rubrics reflects grades assigned by the instructor. Section A average on the assignment was 23.83, and section B average 23.67. Overall course grade averages for section A were 3.65, and Section B 3.63. Course grades are based on participation, attendance, and turning in assignments.

As stated, one of the objectives of the assessment committee is to revise the rubric as necessary. One of the raters provided some input that will be forwarded to the committee:

"I thought it was a challenging assignment to rank them by the criteria. I had some trouble with the optional criteria, in particular, as I wasn't sure always how they should apply to this assignment. Mostly, I didn't consider those marks in calculating an overall score."

Dr. Damron provided another quote: "In working closely with the two, I thought the critical thinking was easier to use—once I decided what I was looking for."

As the university is currently at the benchmarking stage, university-level critical thinking scores are not available for comparison. Informal observations indicate that for a majority of the students (who are predominantly upperclassmen) the scores are in the upper three-to-four range.

Concluding Comments and Future Directions

The main research question was "Are freshman engineering students able to think and write critically?" Based on application of the university rubric for critical thinking to three sections of engineering students, the answer is “somewhat.” The reality is that the rubric predominantly measures critical writing skills. At this point, the authors can only infer that it also measures the thinking skills.

Future data collection strategies need to include a larger engineering cohort. This data should have class level and major information in order to more fully determine significant differences in skill levels. Similar classes of university-wide students need to be appraised. There currently is very limited data on university freshman and most classes do not present them with the types of assignments that require critical thinking and writing.

To emphasize further connections between discipline and writing and critical thinking skills, the authors have developed a student cohort for fall 2007 that would be clustered in a paired composition class and Engineering 1111. Writing and critical thinking skills would be compared with a control group that was not paired. An initial assignment would be given to the students that would assess their beginning skills. Course content and projects would be given to the students in the two classes to expose the students to critical writing and thinking skills. A final project would be given to the students to determine the effect of the interventions. The authors have also discussed asking the research question a bit differently (“To what extent do the students critically think and write? As opposed to “Are they able to critically think and write?”).

The inter-rater reliability information provided some interesting questions for future research:

1) How effective are norming sessions on reliability?
2) How do engineering faculty see writing and critical thinking differently than English faculty?
3) How reliable and valid are the Oklahoma State University rubrics for writing and critical thinking?

Since the work of helping students mature in their writing and critical thinking skills is a developmental process, future work might consider how to develop similar approaches for higher level students. The impact on upper-level discipline-specific courses would be determined through the use of the same writing and critical thinking rubrics and compared with the freshman results.

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