AC 2011-684: BUILDING A TRANSFORMATIVE CLASS FOR FRESHMAN STEM STUDENTS TO THINK AND ACT LIKE CREATIVE, THOUGHTFUL FUTURE SCIENTISTS

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Building a Transformative Class for First-Year STEM Students to Think and Act Like Creative, Thoughtful Future Scientists

Abstract

Turning a required first-year composition class for STEM students into a transformative college experience is a challenging task. Along with improving fundamental writing skills, encouraging students to think and participate in class discussions, to question sources of information, and to entertain different points of views are just a few of the cognitive skill that need development for scientific work. With the help of the First-year Interest Group (FIG) program, which linked this composition class to the Grand Challenges course, the class was able to provide the students with a common intellectual experience as well as a broader sense of a learning community. In order to quickly engage the students, and encourage them to think like "experts," the composition class first focused on the students' use of social media and games. Introducing the contemporary topics of social media and game-based learning immediately drew students into the course as they monitored their computer use, or played and evaluated different educational games. In class they became the experts as they discussed their findings, and this feeling of ownership continued into the semester as they explored parallel themes that over lapped with the Grand Challenges course. Class discussion flourished because students were required to write a three part structured reaction paper for each assigned reading that included a summary of the author's main points, a discussion of the author's sources and finally their critical reflection on the material. Pre and Post surveys of each student's view of their future role in science and engineering were conducted to determine any change in perception or attitude. Further weekly emails sent by the students were collected to determine their growing awareness and confidence in their understanding of each week's reading and discussion. In response to the reading assignments on media and learning, a few students generated their own digital documentaries of student life. The findings from pre and post class surveys, along with the final anonymous student evaluations, indicated that most students found the class helped them become clearer about their professional goals as well as improve their technical writing skills.

Introduction

Maximizing student involvement and retention in science, technology, math and engineering (STEM) still remains a challenge. As noted by Astin and Astin [1] and again by Seymour and Hewitt [2], approximately 50% abandon the physical and biological sciences, and approximately 40% of those potential majors in engineering switch to non-science courses. This lack of persistence in pursuit of a STEM major has generated numerous studies and explanations. An extensive study by Seymour and Hewitt [3] of STEM majors who persisted in the field, as well as those who changed their field of study, found a common core of complains among the students. The students claimed they were turned off by a competitive culture that grades on a curve, poor quality of undergraduate teaching, lack of classroom discussion, and little direct contact with professors who taught the classes. Haag & Collofello's [4] research supports these findings while adding the need "…for learners to understand the impact of engineering solutions in global and societal context." In another study of freshman and sophomore engineering students, researchers found that some students had "low exposure to engineering," before college, which may contribute to their "unsure intentions" to purse an engineering major. [1]

Recommendations for strategies to improve persistence rates at the undergraduate level generally are based on best practices that serve to answer the deficiencies cited above. A partial list of these improvements would include the following: smaller class size or discussion groups, creating hands-on design classes, improving advising, and interviewing practicing engineers. Implementing these best practices in a specific classroom is a challenge, not only to the individual instructor, but also to colleges and departments as well. A particular challenge for STEM teachers is to reduce what Seymour and Hewitt call "the chilly climate hypothesis," namely a classroom atmosphere that causes attrition in STEM areas.

One solution to this perception of a "chilly climate" is Susan Engel's [5] call to turn college classrooms into transformative experiences. Engel focuses on three elements to encourage students to think and participate in transformative class discussions that include the following: 1.The chance to think like an expert, 2. The chance to come up with new ideas, and 3. The chance to be part of an intellectual group. In many ways these goals overlap with other findings to improve STEM education and student retention. For example, Daempfle [6a,b] calls for increased faculty involvement with students along with actively engaging students in an integrative curriculum that helps students see relationships between the disciplines and their professions. Volkwein &Cabrera [7] stress the importance of encouraging student participation and perspectives, and William Knight [8] stresses the importance of learning communities that link courses together to encourage deeper understanding of the course material. This study was informed by these proposals as it attempted to create a transformative classroom experience for first-year students enrolled in a composition class for engineering students.

The Classroom Context

The composition course of this study is part of the first-year experience in the College of Engineering that is offered within the Technical Communication Program. The course description in the catalog includes the following:

> "Emphasis on writing and critical reading; planning, preparing, and revising informative and persuasive communication; adapting writing for intended audiences; grammar, usage and style; critical reading of prose models in the sciences and humanities; using information resources; videotaped oral presentations; collaborative writing using computers."

Along with these "standard" goals for composition classes, the university also sets the goal of improving retention and academic support for new students, particularly for under-represented groups in the STEM fields. These high expectations pose a challenge for a two-credit composition class. In order to meet these challenges, the instructor for this class has been engaged in a continuing Action Research process exploring how to develop an intellectual community to help students identify as potential engineers or scientists. In the past Courter &Johnson [9] focused only on first–year interest groups (FIGs), consisting of students taking several courses together that ideally are linked by themes. This past study found some success in building an effective learning community through extra-curricular activities such a participation in a ropes course, in addition to taking two classes together. Based on written samples submitted by the students, it also concluded that most students managed to communicate moderately well as a technical writer. The past research also suggested exploring other science courses that would enable a better content link to the material presented in the composition class.

The present study includes a FIG class that was newly linked to InterEgr 102, a "Grand Challenge," course that takes a cross-disciplinary approach to first-year engineering education. In addition, a non-FIG class was included to determine how a shared learning experience, beyond one class, could affect the make-up of the learning community. Students in both sections were assigned readings that overlapped with some of the major themes presented in the Grand Challenges class. The Grand Challenges Class is based on challenges outlined by the National Academy of Engineering (NEA) tacking five themes that contemporary society faces. Thus students in both classes would read and write about such topics as sustainability, clean water, alternative energy including nuclear energy, web based learning, and medical technologies. In addition, as part of the first-year common reading experience, both composition classes read sections from *The Immortal Life of Henrietta Lacks,* by Skloot [10] that focused on the ethics of ownership in human tissue research. This attempt to explore common problems discussed in other science classes, as well the first-year common reading, helped to create a sense of a shared intellectual community, which is another means in the creation of a transformative class.

The Curriculum

Engel's transformative prescription asks for more than "covering' the topics or teaching a generalized concept of critical thinking. Rather she identifies several cognitive skills essential for creative and scientific work. The skills include the ability to reflect on problems through engaging in counter-factual thinking, questioning the sources of information, and the willingness to change one's perspective in the face of new information. The challenge was to structure the class tasks and discussion to elicit these habits of thinking, which are the key objectives in creating a transformative class. To encourage a close reading of the material, which in turn generated critical analysis in class discussion, the following preparation was required for each assignment before the class met to discuss the readings:

A. Sum up the argument or main point of the reading—use direct quotes where needed.
B. Describe and evaluate the evidence used by the authors- you may want to lay out the key points in a short outline.
C. Express what you find compelling or inadequate in the reading, and if you can make connections to other readings and topics discussed in class.

To encourage everyone to participate at some level, often students were asked to share their responses with each other before the whole class discussion. As much as possible, the class discussion was structured, in Engel's [5] terms, " to guide students to think about the source of information, entice them into constructing counterfactuals, maneuver them to take the perspective of another, and insist that they consider an idea deeply without accepting it." In addition to the required critical reflections mentioned above, each student was asked to send a weekly reflection in the form of an email to the instructor. This became an important one to one conversation where students shared any insights or questions they had about the course work. The weekly emails also provided an opportunity for students to expand on class discussions in a give and take format with the instructor. Formal writing assignments included three essays varying in length from 800 words to a minimum of 2,000 words. The first essay related to their use of social media, the second essay was a technical report on a current challenge in either engineering or science, and the last essay required a counter argument on social and technical issues suitable for publishing in a college newspaper.

The Analysis

The methods for determining how well the objectives were met consisted of the evaluations of student's course work described above and the administration of pre-class and post-class surveys. In the pre-class survey, students were required to explain their career goals and the amount of social media they used. In the post-class survey given at the end of the semester, (See Table 1) students were asked if their current career and academic goals had changed, if any of the articles read in class influenced their views towards their career and science, and if the study of social media changed any of their habits. A separate question for the FIG group asked if studying similar topics in both classes had any affect on their learning experience. As shown by their responses in the post-class survey, the data suggests the class played a transformative role for students in both classes. In the case of the FIG group, they cited the linked classes as deepening their understanding of the readings in science and engineering. In the following discussion several of the thematic units presented in class are used to highlight student reflections and responses that in turn reveal the process by which these classes became transformative.

The first week of class began with a chapter from Henry Petroski's *To Engineer is Human: The Role of Failure in Successful Design* [11] and an article by William McComas [12] titled "*Ten Myths of Science: Reexamining what we think we know*." The chapter from Petroski's book, titled "*Engineering as Hypothesis"* introduced students to the engineering process of predicting and preventing failure through the testing of various hypothesis, while McComas's article attempted "to refute several of the most widespread and enduring misconceptions held by students regarding the enterprise of science." The paired readings presented insights into how a

professional engineer works while also challenging some traditional misconception about the nature of how science is practiced. The students' critical responses reflected their new perspectives. One student wrote: "I had never realized all the flaws and misconceptions about science and hypothesis that have flourished in modern society... the scientific process is not a set of rules that everyone follows, but a set of guidelines that can be deviated from…" Another student wrote at the end of the reflection, "I must make sure to use a more careful thought process when attempting to gather information, and understand how conclusions can be made, and more importantly, when they cannot be made." Lastly one student expressed the desired skill of questing sources with a healthy skepticism: "This class is helping me to be a more critical thinker and not to take everything I read as a fact." This healthy skepticism, according to Engel, is one of cognitive skills necessary for creative and scientific work as well as an important element in a transformative class.

The next set of readings was designed to appeal to this generation of students who view technology as life, not a separate reality, and privilege graphics and animation over text. The readings included an article about students addicted to social media and an evaluation of educational games, by Richard Van Eck. [13] The students also read an interview with professor James Gee, the author of *What Video Games Have to Teach Us about Learning and Literacy* [14]. Focusing on their use of social media and game playing immediately drew the students into class discussion. The first assignment asked each student to keep a log for four days of how they spent their time, including their use of social media, and display the results in a pie chart that could be shared with the class. To prepare for playing and evaluating educational games, they read, "*Digital Game-Based Learning: It's Not Just the Digital Natives Who Are Restless* [13], which claimed game based learning is effective and engaging because games involve analytical thinking, risk taking, and progressive challenges involving choice. Students were then asked to go to the *Tiltfactor,* [15] a collaborative laboratory that makes screen based computer games, and play their game *Layoff*. The game *Layoff* attempts to comment on the current state of the US financial crisis by asking players to lay off workers to save the corporation money, but not allowing the gamer to eliminate white-collar executives.

The class discussion that followed this assignment allowed the students to show that they were the experts in analyzing games. They compared their observations about the educational games to other games they had played, and argued about whether-or-not video games influenced violent behavior. Further they suggested other sources for educational games and as a result *fantasticcontraption.com* [16] was added to the curriculum. The resulting critical reflections were some of the most extensive and insightful of the semester. One student wrote this reflection drawing together previous readings with the current assignment: "In this reading, I found it particularly interesting that video games embody the process of cognitive disequilibrium and resolution more than other techniques of learning. This was an idea I was previously unaware of…" The student continued, "With our previous readings on hypothesis, I also found the fact that interacting with games requires a constant cycle of hypothesis formulation, testing, and revision to be compelling." Calling on extensive knowledge of game playing, as many of the students did, this same student found the game *Layoff* useful, but too simple and similar to the game *Bejeweled.* Generally the class found *Layoff* too simple, but they took pride in the amount of money they saved the company by laying off workers. As one student ironically noted, "In the end, I pulled off a 6.9 billion dollar money saved high score, sending countless non-businessmen

to the unemployment office at the bottom of the screen." Only a few students articulated the designers' hopes that players would begin to experience empathy for the people they laid off, and therefore become critical of the elite managers whom they could not remove.

Evidence of student awareness of the curriculum linkage was seen in this student's response: "From a reading in InterEgr 102, it stated that web-based and computer learning is the next and most important step in better and more individualized learning." Another student picked up on the need for more research before claims about gaming and learning can be made with this comment: " In order for people to truly believe the positive effects playing games can have, there needs to be studies on how and when to integrate them into the learning program." Some gamers in class pointed out that, "we can learn from anything, even the worst most violent game, but what we learn is the difference."

Another element in the social media unit included watching A *Vision of Students Today* [17] created by Professor Michael Wesch's class in Mediated Culture. It depicts a bored and alienated student body sitting in large lecture hall in front of a traditional lecture presentation—just the opposite atmosphere of a transformative class. Inspired by this video and the class discussion of media use, several students decided to make a video exploration of their first-year experience. Interestingly one of the videos featured four different first-year students each of whom narrated their struggle to find a balance between studying, partying and attending football games. As a "cautionary tale" for new students who struggle to meet the challenge of STEM courses, this video has become part of the curriculum and was shown in other classes.

The post-class survey question (See Table 1) on media asked: "After our study of social media have any of your media habits changed? If so how? As expected from this generation of students, 16 responded that their media habits were about the same as before the class, but 10 students indicated that they were more aware of their media use, and 8 students noted that they had changed her habits. One student who changed her habit wrote: "Yes when studying, I really try to avoid media such a Facebook because it serves to distract me." More often the comments were, "My habits have not changed, but I am more aware of the connections."

Table 1: The results of the post-class survey

Q1. Today what are your career and academic goals? Do you know you major area of study?			
	Clarified career and academic goals	Decided to leave	Kept original goals
FIG	6	4	7
Non-FIG	12	1	6
Q2. After our study of social media have any of your habits changed?			
	Stayed the same	More aware	Changed
FIG	7	5	4
Non-FIG	9	5	4
Q3. Have any of the articles we read in class and /or the research paper you finished influenced your views towards your career and science in general?			
	Strong influence	Some influence	Little influence

FIG	2	10	4
Non-FIG	2	12	3
Q4. What affect did studying similar topics in this class and the Challenges Class have?			
	Positive affect	Little affect	
FIG	15	2	

Discussion

The unit on social media sparked student discussion as evidenced by this reflection: "I really enjoy coming to 155 because everyone has a lot of insight into the problem surrounding video games." This pursuit of knowledge in collaboration with other students is an important marker of community building. The readings and discussion led to the first essay that required students to analyze and evaluate one example of social media or technology and the impact it has made on society. In preparation for the essay, one student wrote, "I am getting excited to write our next paper because I have found a topic I am passionate about." This passion for learning combined with a shared sense of community is another marker of a transformative class.

At the beginning of the semester all of the students expressed a desire to get a degree in engineering, although many were not sure which specific field held their interests, and some only expressed a general desire to get good grades. In order to help students weigh their career choices, the readings were designed to involve them in thinking about the challenges of science as well as to imagine their role as future engineers or scientists. The success of this process was noted by one student who wrote: "Both readings (from the first unit) point to the theme that engineers today need to be creative and constantly challenge what is thought to be true. Engineering ties together the elegance of art and design with the precision and knowledge of science. I can fit into this role very well. I will use my creativity and problem solving skills to help solve problems with unique solutions." Another student wrote: "Engineers need to commit to their work and be able to perform well on a team, as a leader and as a follower. I think I would be an excellent engineer because I am hardworking and I love challenges. I also think I have great communication skills and hope to become fluent in Spanish so I can work in international business."

As the semester progressed a number of the readings in the FIG class overlapped with topics in the Grand Challenges class as both explored alternative energies, the problem of supplying clean water, and the development of stem cell research. As a result, students found a common ground of intellectual discourse, which helped to create as sense of continuity and community. For the non-FIG class, these links may have been weaker, but their robust class discussion, and their active participation in producing two videos helped to create a sense of community exploring many of the same issues as the FIG class.

Along with focus on discipline related topics, the class stressed the requirements of technical writing by providing various models and templates. The students were first introduced to articles in the Science Section of the New York Times as an example of writing that exemplifies the clarity and conciseness needed to explain technology and science to the average reader. In addition, the international template known as IMRaD, (Introduction, Methods, Results, and

Discussion) was explained and modeled from articles found in peer-reviewed publications. This was done in preparation for the students' own technical report on research topics that represented current challenge in technology and science. Many students choose to report on sustainable and alternative energies, while others explored the use of steroids in sports, the historical development of a code of ethics for tissue research, and the ergonomic improvement of the lap top computer to name a few.

At the eight-week mark, some students realized that they were drawn to other subjects, and exceptions were made for their report topics, which included a history of Hmong migration that focused on the challenges and discrimination that Hmong students face in higher education. It should be noted that part of the FIG mission is to reach out to under-represented groups to increase their retention in college, and indeed four of the students in the FIG sections were Hmong students. Thus the writing on Hmong history added an important dimension to the class as well as to the confidence of the author who wrote the report. As each student was also required to make a seven-minute presentation on their topic before class, this part of the assignment gave the Hmong student, and others as well, the satisfying role of becoming a partial expert in the field. As Engel points out, this chance to think and act like an expert is another important element of the transformative class.

Taken together, did the science and technology focus of the curriculum, along with the writing of the research reports for both classes, help students to make more informed choices about their future career and academic goals? There is some data to indicate that it did. A post-class survey asked: "Today what are your career and academic goals? Do you know your major area of study? Among the FIG students, (see Table 1) seven wrote that they had the same career goals that they had at the beginning of the semester, while six students indicated that they had become clearer in their goals, and four students said they planned on leaving engineering and changing to a different major. It should be noted that three of the four students, who decided to change majors, were first generation students whose families may have provided only a "low exposure" to the engineering profession-- a factor in the persistence of engineering education [(18).] For the non-FiG class, six said they had the same career goals at the end of the semester as they did at the beginning, but twelve said that they had gained a clearer focus on their careers, and only one said they would leave engineering.

Students who gained a clearer focus about their goals often moved from just a career in science to a specific field. One student, whose goal at the beginning of the semester was to graduate from college as a biomedical engineer wrote, "Today I want to be an engineer for aeronautics; I plan on majoring in mechanical engineering and aeronautics." Another student in the first survey wrote, "Foremost I would like to graduate, beyond that I haven't given it much thought," but finished the semester with this goal: "I am planning on majoring in Engineering Mechanics and astronautics… I would like to do something in space."

Unfortunately the survey did not directly ask why students decided to discontinue their study of engineering, but some of the students revealed their motivations to make this change in their comments. One student wrote, "My goals have shifted since the beginning of this year; I want to major in political science." Another student, who was interested in the ethical debates that included a discussion of the use of Adderall, commonly used to treat ADHD (Attention Deficit

Hyperactivity Disorder) as a study aid, decided to major in philosophy and law. For some, the readings helped them understand why they may not want to major in engineering. One student with this perspective wrote the following: "Reading some of the engineering articles gave me a clear view of what engineers deal with and I came to the realization that this isn't my passion." That student did research on lung cancer and decided to switch to studying sports therapy.

To specifically elicit a response about the curriculum, the post-class survey included this question: "Have any of the articles we read in class and/or for the research paper you wrote influenced your views towards your career and science in general?" Twenty-three of the students claimed the readings had some influence on their views, while four students claimed that it had a strong influence on their views, and eight students felt the curriculum did not have a particular influence on their views. A sample from this last group revealed that often they already had clear career goals, and as one student noted: "None of them had a profound influence on me; my plans have been in place since before I took this course." That same student, however, noted this about the shared themes between the two classes, "We wrote about some of the same topics so my understanding of these topics was better than it would have been. This made some of the writing easier and helped me to do better." Students often cited specific topics or readings that influenced them. For example, one student wrote, "The articles which influenced me the most involved the environment. I am very interested in protecting the environment and understanding what harms our populations. These articles have made me consider other career goals." Another student wrote, "My technical paper increased my interest in Robotics and AI. This course did reinforce my decision to go into engineering. It provided me with an opportunity to look into the careers of engineers and see what they do, and I liked what I saw." Sometimes the topics and research took an opposite affect as one student wrote: "The research paper that I wrote helped influence my decision to go into pre-med, because researching the different types of surgeries sparked my interest in the medical field even more."

For the FIG group the final question asked, "What affect did studying similar topics in this class and the Challenges class have? Only two students did not find strong reinforcement or links between the classes, while the other fifteen students noted a positive affect. One student wrote, "By studying similar topics, I was able to gain a deeper understanding of the assigned topics." Another added, " I loved the content overlap between InterEngr 102 and EPD 155. I was able to do two projects on hydrogen fuel cell vehicles, which I found very interesting. I would definitely recommend FIG to anyone interested in engineering. " And finally this comment, "I had a good background on energy coming into102 class because of the EPD 155 class."

Conclusion

In conclusion, the goal of creating transformative class as defined by Engel [(5)] was successful. The required reflections, the class discussions, and the weekly emails to the instructor helped to create multiple levels of discourse and analysis. On many levels, the students demonstrated an ability to reflect on problems, question the sources of information, and showed a willingness to change their perspectives in the face of new information The survey indicated that a majority of the students clarified their career and academic goals, and that a majority of the students were influenced and even excited by the curriculum assignments and class discussions. It is true these claims are based on evidence from student voices, articulated in weekly reflections and

expressed in their written assignments, and therefore do not represent a large sampling, but these voices reflect on honest engagement with the class and curriculum. Taken as a whole, they can serve as encouragement for others to experiment with building their own transformative class.

Postscript

The anonymous course evaluations taken at the end of the semester also reflected these findings. The overall rating of the course was 4.88 out of a scale of 5 for non-FIG class and 4.72 for the FIG class. The following are a few comments from the evaluations that seem to summarize the experiences described in this article.

"I enjoyed the discussions because they really gave me many points of view."

"I found the class discussions most useful as they made me think and analyze the topics on a deep level."

" I feel both my writing and speaking improved from this course. I received good feedback on my work that helped me identify my strengths and weaknesses."

And finally this comment from an email reflection: "This week was a wonderful experience for me because I learned how to summarize an article and provide evidence for an argument. I learned that using quotes in my writing can help me back up my thoughts. I loved the reading material from this week because it kept me interested the whole week…I enjoy coming to this class twice a week and I look forward to riding my bike to class. I think you have a fun way of relaying important information, and I admire that you want to learn from students."

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