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Thermodynamics in High Rhythms and Rhymes: Creative Ways of Knowing in Engineering

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ABSTRACT

Thermodynamics is a foundational course in nearly every engineering program. In a traditional classroom, instructors focus on the analysis of thermodynamic energy systems and their application to real world contexts. Because these complex systems can be difficult to understand, some instructors encourage students to tap into their creative side and translate thermodynamics into a language they can clearly understand. In this study, the instructor of a sophomore-level engineering thermodynamics class asked students to generate a creative interpretation of Thermodynamics. The presentations were a high-energy event in rhythms and rhymes, as students presented their creative work; evaluation shows the creative interpretation helped clarify course concepts and increased students' appreciation of thermodynamics and the engineering profession. This study further investigates the relationship between students' performance on problems and final exam scores [$N=147$]. Results indicated that students' engagement in creative presentations contributed to their learning on the topic chosen by students in their creative entries.

Key words: Creativity, engineering education, thermodynamics

"Thermodynamics, what a wonderful class.

It's what Dr. B teaches us, with a tad bit of sass.

We learn about heat energy, and what it can do.

She makes it so fun and easy to learn, for me and for you."

Created by Kaamil Dill



INTRODUCTION

Globally there are calls for “coupling creativity and education” in order to prepare students for the demands of 21st century professions (Shaheen 2010, p.168). Even in the face of “the stereotype that science is dictated by unyielding facts and figures, with little room for ambiguity and creativity,” many educators are developing creative assignments (Stockwell 2016, p.95). Engineering educators rely on a broad and deep repertoire of pedagogical methods to motivate and stimulate student interest and engagement, and some of these methods might be considered “creative.”

Over the past 50 years or more, creativity has moved from the narrow definition of “self-expression” to become a prominent concept in learning and teaching. Whether “teaching creatively” or “teaching for creativity,” innovative pedagogies that foster opportunities for students to develop creative products have been associated with enhanced learning and student empowerment (Craft et al 2001; Collard and Looney 2014). Although many instructors avoid the risks associated with creative assignments and let the products of evaluation (essays, exams, lab reports, etc.) continue to take familiar forms within disciplines, many others are attracted to contemporary views of creative ways of knowing and doing.

In a recent study of how developing creative products might improve scientific literacy, Stockwell offered students options “to communicate a message through an artistic piece. . . including poems, photo or videography, and fine art or folk pieces” (p. 95). Findings were positive for improving writing skills, increasing interest in the field, and fostering critical thinking. The potential for transformative learning seems inherent in teaching creatively as well (Coate and Boulos 2012).

Specific to engineering instruction, comparative results showed improved performance and satisfaction in a thermodynamics class following pedagogical changes such as including “active learning” (students designed a mock television game show, for example) and using multimedia to present information (Byerly 2001). In her thermodynamics course, Dillon’s (2014) students created “poems, videos, collages, songs, sculptures, devices, and photographs . . . [which led to] the realization that ‘thermodynamics is everywhere’ at the completion of the art project” (n.p.). Zietlow and Henderson (2012) introduced the League of Imaginary Scientists and asked students to create videos that depicted entropy. Many more engineering instructors are including creative activities in their courses, as evidenced by dozens of recent conference papers, yet the learning outcomes are not always documented. One assessment, however, suggests “integrating creativity in pillar courses to foster meaningful development of students’ creative thinking” (Husted, et al., 2014).

In our study, over 150 students in a thermodynamics course presented their understanding of thermodynamics’ topics through a creative channel, such as poems, comics, songs, short stories, and videos. Introducing opportunities for creative expression of learning is a form of teaching creatively and invites alternative ways of “making learning visible,” but assessing such learning is



a challenge (Collard and Looney, p. 351). The instructor of the course in this study “believes that creativity is important across subject areas (and not just the arts) and that all learners are capable of being creative” (Collard and Looney p. 358), yet she also realized the challenges inherent in actually showing how student engagement in creative presentations contributed to their learning.

Considering the “How People Learn” framework (Bransford, 1999), a learning environment developed to be learner-centered, knowledge-centered, assessment-centered and community-centered can support the learning cycle. In the case of the course we describe here, the instructor designed an assignment that would place students in the learning cycle and guide them through these six stages (Brophy, 2000):

1. The Challenge - presents a statement or scenario that poses a complex objective for the students. The challenge should be related to a major concept of the course that students should come to understand in order to meet the objective.
2. Generate Ideas - provides students an outlet for showing what they know about the challenge. It can serve as a baseline or pre-assessment.
3. Multiple Perspectives - provide insights on the challenge. These statements or comments from experts do not provide a solution but should help the students see the many dimensions to the challenge.
4. Research and Revise - engages students in learning activities linked to the challenge. These can be readings, homework problems, simulations, or other activities.
5. Test Your Mettle - application of what students have learned and evaluation of what they need to know more about. This step helps students reflect on and synthesize what they know.
6. Go Public - provides students an outlet to demonstrate what they know at the end of the module. Going public may involve a presentation to their classmates and/or an audience outside the course.

The approach and findings described in this study can increase our understanding of how/if creative or alternative products enhance learning in engineering, in particular. Asking students to apply concepts through “multiple representations” (Kozma, 2003; Wu & Puntambekar, 2012) promotes active engagement in the learning cycle as well. In this project, students engaged with new representations of familiar concepts in thermodynamics by creating poems, songs, short movies or comics and the Go Public stage of the learning cycle offered a presentation to their peers and the University community. Whether the creative endeavors strengthened student learning of the concepts is the impetus for our research.

DESCRIPTION OF THE INNOVATION

This study investigates if there is a relationship between students' performance on the course final exam that assessed knowledge and how that knowledge is connected to developing a creative entry.



Inspired by her former professor of psychology, the instructor of this sophomore-level engineering thermodynamics course adapted an activity done in an upper-level personality psychology course (Wesselmann, Kassner and Graziano, 2016). Students were asked to generate an “entry” for a contest by choosing from the following entry forms: song, poem, short story, short movie, comics, or whatever form a students’ creativity took. The only requirement was that the entry needed to illustrate a thermodynamics concept covered in the course. The class evaluated these entries and voted on their favorites in a tournament-style bracket system; winners received gift books related to the science of energy in addition to the assigned credit.

Creative projects were introduced in a sophomore level semester-long course, Introductory Thermodynamics, offered two fall semesters at a large Midwestern public research university. The creative project was one of the course assignments, worth 10% of the course final grade. In addition to developing the project, students competed in the presentation contest the week before the final exam. Each student submitted an entry, which was an original poem, short story, comic, short movie or video, or other format, that they believed epitomized an important course concept of their choosing. These entries included an explanation of how the creative product illustrated the concept. Because of the large classes, we matched submissions for content in a tournament bracket with teams of four in matchups. Based on originality, each team selected one creative entry to represent the team in the contest. After all entries in a matchup were presented, the entire class voted on which entry better illustrated that particular course concept. The winner of each matchup then advanced to the next round. First, second, and third place winners received gift books related to the science of energy.

ASSESSMENT

To assess the effectiveness of developing a creative project to demonstrate the learning of a Thermodynamics concept, we used quantitative methods to address the following hypotheses:

- H1:** When students choose a creative medium to present concepts from Thermodynamics, they attain scores statistically better than an average score, when answering questions related to the concept that was the topic of their creative entry.
- H2:** There is a significant difference between student performance on a final exam question related to their creative project compared to others who did not develop a creative project for the same concept.
- H3:** Students positively evaluated the value of creative projects for their learning of Thermodynamics.



Data Gathering Method

Data were collected from two semesters (fall 2013 and fall 2014), with sophomore students ($N = 151$, 17 women) enrolled in a semester-long, Introductory Thermodynamics course. Several sources of data were used to assess the impact of the creative project. At the end of each semester, students completed an in-class survey that consisted of seven items asking the students about their experiences with and their perceptions of the creative project and the overall learning environment. We adapted Wesselman, Kassner and Graziano's (2016) survey items and modified these items to reflect on the subject and essence of the course and the creative project (e.g., "The creative project encouraged me to think about the course concepts in novel ways," "The creative project increased my excitement for the course material," "The creative project increased my appreciation for the engineering profession," 5-point scale; 1 [*not at all*], 5 [*very much*]). The survey questions are included in Appendix A. To investigate if student engagement in creative presentations contributed to their learning, we looked at students' performance on particular problems in the final exam, assessing for knowledge on the topic chosen by students in their creative entries.

Data Analysis

To analyze survey results of the students' self-reported outcome measures, descriptive statistics analysis was performed. We selected questions from the final exam, assessing knowledge of course content reviewed in the students' creative project (First and Second Law of Thermodynamics, Heat Transfer, Entropy, etc.). Then we compared students' performance on these questions to students' performance on the same questions whose creative projects were not focused on the same topic. For example, all the students whose entry was on the First Law were compared to all the other students who did not create an entry on the First Law. Out of 151 students 147 completed the final exam ($N = 147$). For topics in which more than three students had done a creative project, only those categories were analyzed using one-sample t -test. In addition, we only analyzed the creative entries that were more than four, for example the only one experiment, three games, and the four song entries were not included in the analysis. All study analyses were performed using JPM 2016 software.

RESULTS

Surprisingly for engineering students, the poems in both classes were the highest ranked entry chosen by the students, followed by short stories and videos (short movies). Their work presented a variety of creative entries - from poems, songs and comics, to short stories, animated films and

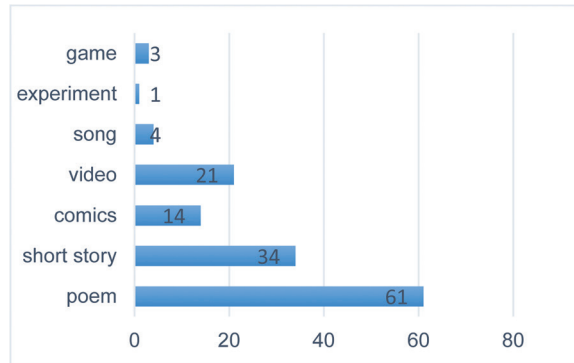


Figure 1. Creative entries in thermodynamics class.

videos or drawings. Figure 1 indicates the number of students who chose to do a particular entry of the creative project, combining the two semesters. Students had the freedom to choose the topic and the type of creative project. The topics that students selected were aspects of the Laws of Thermodynamics, entropy, energy transfer, mechanical work, systems and surroundings, and Thermodynamics cycles (Figure 2).

In regards to the type of chosen entry overall (both semesters), students who did comics in their creative project scored higher on the final exam compared to those who wrote a poem or created a video. On the other hand, in the fall 2014 semester, students who created a video scored higher in the final exam compared to those who wrote a poem (Figure 3). The results from the t -test completed to compare 2013 and 2014 semesters indicated a significant difference in students' final exam performance between the two years (Figure 3 and Figure 4). However, Tukey-multiple comparison test confirmed that the type of entry did not significantly affect students' performance on the final exam.

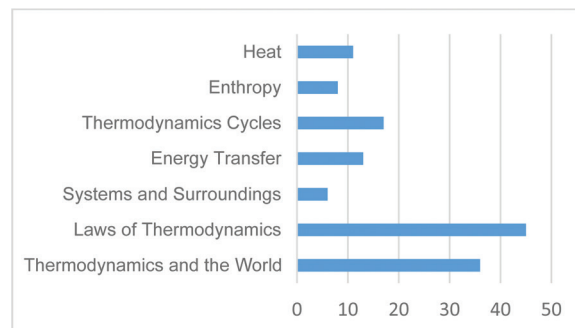


Figure 2. Topics chosen by students' in thermodynamics class.

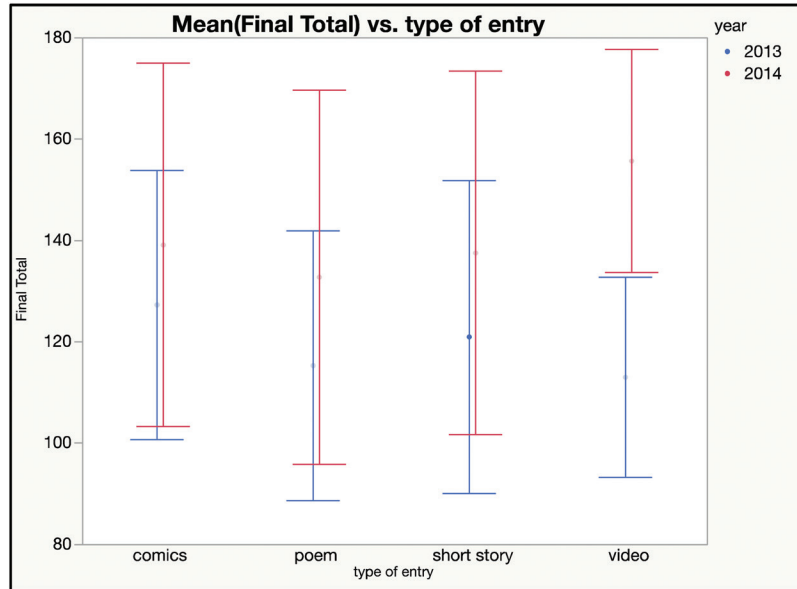


Figure 3. Mean plot of differences between type of project (comics, poem, short story, video) of fall 2013 and fall 2014.

Based on the one-way ANOVA model (Table 1), the year was a significant factor ($p < 0.0012$), but the type of entry was not found to significantly influence the student' final exam score ($p < 0.5619$).

Below are presented some examples of students' creative entries (Figures 5-7). The OER holdings for all creative entries can be found here: <http://ouopentextbooks.org/thermodynamics/>.

All students gave permission for their work to be displayed here and at the open educational Thermodynamics resource and each student retains the copyright to their own work.

The results described below show evidence of the benefits of developing creative projects. These results corroborate our first hypothesis that when students choose a creative medium to present

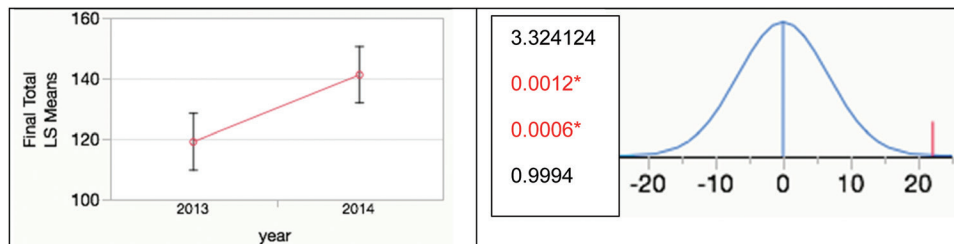


Figure 4. T-test comparing 2013 and 2014.



Table 1. One-way ANOVA Model summary.

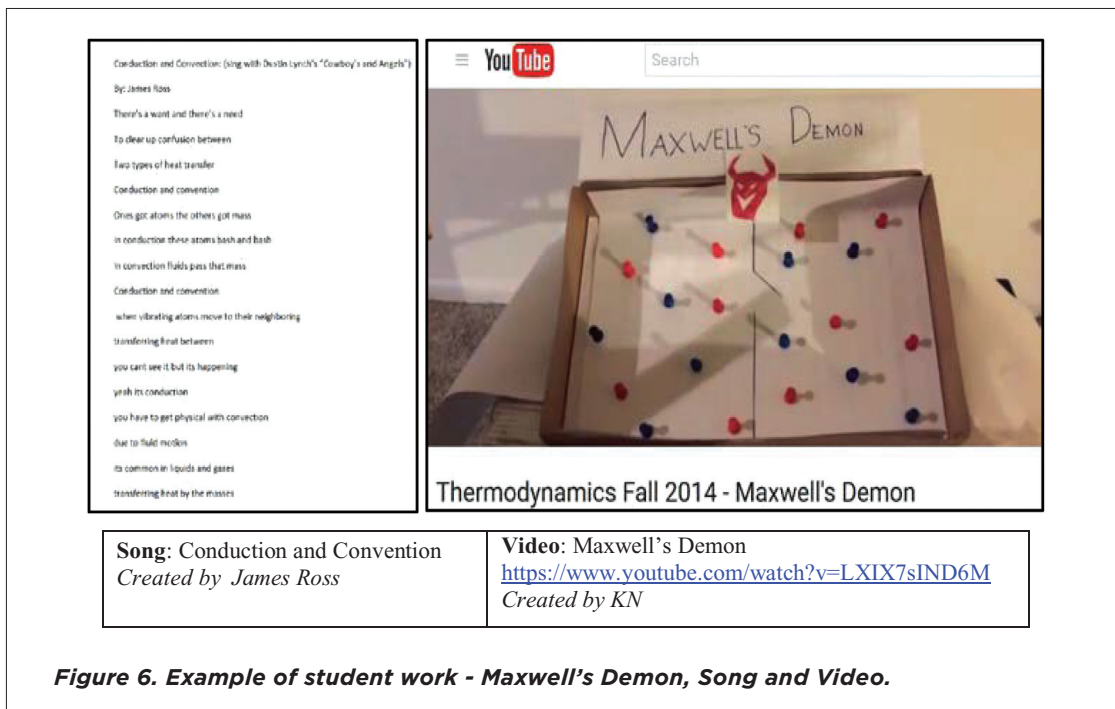
Source	DF	Sum of Squares	F Ratio	Prob>F
Type of entry	3	1956.008	0.6869	0.5619
Year	1	10487.736	11.0498	0.0012*
Type of entry*year	3	2661.815	0.9348	0.4266

* $p < 0.05$.

concepts from Thermodynamics, they attain scores statistically better than an average score when answering questions related to the concept that was the topic of their creative entry. An examination of the final exam questions reveals that most of the students scored higher (over 5) on questions related to the concepts they chose for the creative project (Table 2). We used the one-sample t -test to determine whether the mean of a group differs from a specified value. The comparative value for our study was 5 -, the median value of a possible score of 10 on the exam problem. We chose this value because historically students' performance on similar thermodynamics problems on the assessed concepts is about 50%, as these are the concepts identified by the literature that students have misconceptions and difficulties understanding (Miller et al., 2005). In addition, the problems chosen to compare in the final exam were problems that students needed to solve following a problem-solving technique with eight required steps. This technique was introduced to students at the beginning of the semester and it is a commonly used approach in teaching Thermodynamics. An example of a scored problem is shown in Appendix B. For some of the problems, students were

	<p>1st Law of Thermo (Sonnet)</p> <p>A sound basis for thermo, The first law is there to relate. Known as the Conservation of Energy Principle when though, It's actually a fundamental process occurring between two states.</p> <p>Every bit of Energy is accounted for in a process, Since it cannot be created nor destroyed, Instead it changes form so there's never excess, An energy balance the universe cannot avoid.</p> <p>So let's consider a room where heat escapes through the door, heated by the work of an electrical fan for you. For the energy in the room increases more! By this thermo law work is equal to Q!</p> <p>So long as we were taught by Dr. B, This principle will always be remembered by Thee!</p>	<p>Introduction</p> <p>From a mechanical standpoint, the heart is probably the easiest to describe since it is for the most part a pump. Using negative and positive pressure within its interiors, it is able to fill with blood and push that blood throughout the body. Because of this mechanical view, it would be interesting to view the heart through an engineering standpoint, gain a perspective as to how the heart works and see if there is any thermodynamic concept we can learn from this experience. This is what Eduardo Cesarman and Norman Bradfield did in 1977 when they wrote their article "Thermodynamics of the Myocardial Cell." They took the understanding of the physiology of a myocardial cell and applied some thermodynamic principles to help in understanding the nomenclature of the cardiac cycle. However, in order to really delve into what their article is arguing, we must first examine the heart's physiology and understand how the heart cycle works, second learn about signaling on the cell membrane, and then finally see if we can demonstrate some thermodynamic principles through the heart's functions.</p> <p>The Heart</p> <p>The primary function of the heart, as stated above, is to pump blood throughout the body. We can view this process in two phases: a mechanical contraction phase (systole) and a mechanical relaxing phase (diastole). Briefly, what happens in the cardiac cycle is that the heart will receive an action potential that will tell it to contract. The heart muscles will contract on themselves and push the blood within the heart through the rest of the body. When the muscles relax, the interior volume of the heart will increase again, creating negative pressure and will pull in blood from the venous side of the circulatory system. The cycle will continue again, and we have blood pumping through the body.</p>
<p>Comics: Batman and Thermo Created by Douye Allisoap</p>	<p>Poem: First Law of Thermo Created by MB</p>	<p>Short story: Thermo Heart Created by Khiem B Nguyen</p>

Figure 5. Example of student work - comics, poem, short story.



provided with multiple choice numerical answers; however, they needed to show their work in order to receive full credit. In this regard, partial credit was given for each of this type of question. On a grading scale 0 to 10, the mean was used to compare student's scores on an individual problem. The final exams were the same for both cohorts with the only difference of changed numerical values. The exam questions were adapted from Cengel and Boles' *Thermodynamics: An Engineering Approach, 7th edition*, textbook, widely used in the undergraduate aerospace and mechanical engineering curricula. Problems were chosen by different levels of difficulty, based on the textbook classification of basic, average, and advanced questions.

A one-sample *t*-test was conducted on the students' problem score to evaluate whether their score was significantly different from 5, the median of possible scores for a problem performance. For example, the sample mean of 8.4 on a question related to Laws of Thermodynamics ($SD = 2.00$) was significantly different from 5, $t(22) = 8.20$, $p = .000$. The 95% confidence interval for the students' problem mean ranged from 7.570 and 9.308. The results support the conclusion that students whose creative entry presented on a Law of Thermodynamics scored higher (over 5) on questions related to the Law's concept than the average. Table 2 below summarizes all results for each concept. We present the one-sample *t*-test only for the topics in which more than five students had done a creative project (Table 2).



Table 2. Results of one-sample t-test and descriptive statistics for problem scores and students' creative entries by concepts

Concept	M	SD	N	p-value	95% CI for Mean Difference	t	df
Laws of Thermodynamics' 13	6.20	1.78	25	.003	0.461, 1.930	3.36*	24
Laws of Thermodynamics' 14	8.44	2.00	23	.000	2.570, 4.308	8.21*	22
Thermodynamics & the world' 13	5.88	1.75	16	.063	-0.556, 1.806	2.00	16
Thermodynamics & the world' 14	6.69	2.15	19	.003	0.654, 2.724	3.43*	18
Thermodynamics Cycles' 13	8.47	2.32	9	.002	1.689, 5.255	4.49*	8
Thermodynamics Cycles' 14	5.42	1.88	6	.611	-1.558, 2.391	0.54	5

*p <0.05.

Table 2 shows that there were increases in means with significant differences in most concepts. Problem performance for the students whose creative entries reviewed the respective concepts was statistically different, at the .05 level of significance, from the normed value of 5. Though not statistically significant, there were increases in means in Thermodynamics and the World in fall 2013 and in Thermodynamics Cycles in fall 2014.

To compare differences between the two semesters, Wilcoxon signed rank test was performed on the topics Thermodynamics and the World, Laws of Thermodynamics, and Thermodynamics Cycles. Test results shown in Table 3 below indicate that there is a significant difference between scores of the two semesters on Laws of Thermodynamics and Thermodynamics Cycles. Students' scores on Thermodynamics and the World did not show a significant difference.

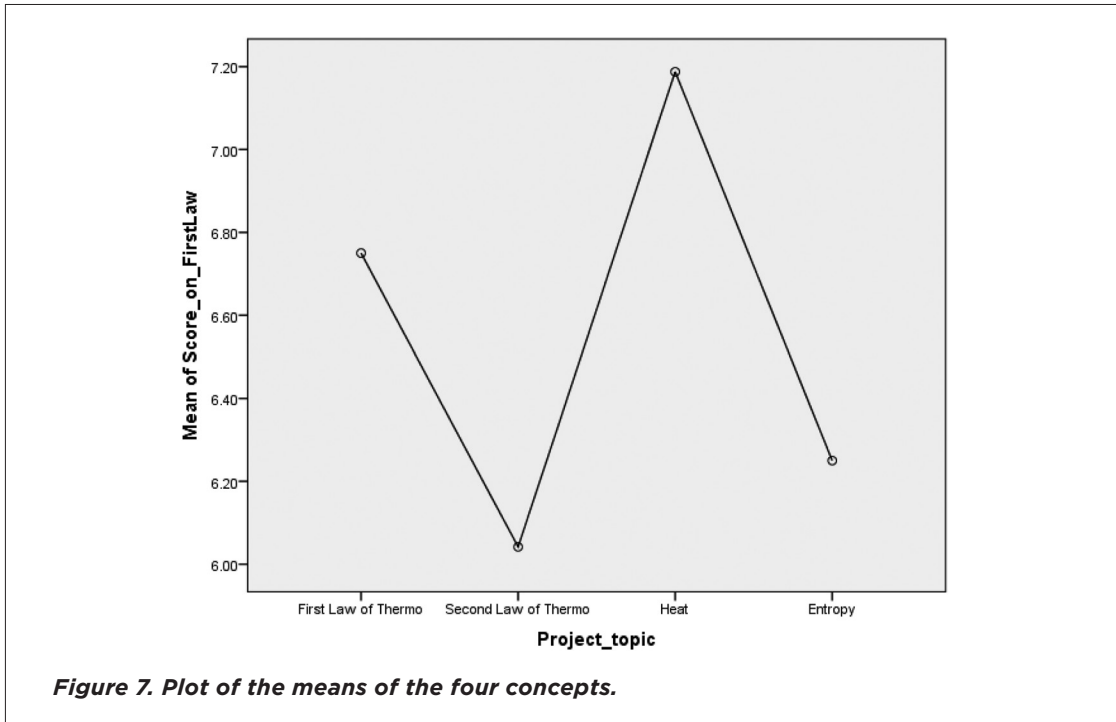
To address our second hypothesis, and to further explore the effect of the creative project on more specific concepts and how students performed on questions related to that particular concept on the final exam, we further subcategorized the groups. We categorized "Laws of Thermodynamics" into two categories - First Law of Thermodynamics and Second Law of Thermodynamics. We also chose to explore differences in scores on topics considered some of the most difficult concepts in Thermodynamics, such as Heat and Entropy.

Since there was no significant difference between categories, we combined data from both semesters and found 20 students with projects on First Law of Thermodynamics, 24 students

Table 3. Results of Wilcoxon signed ranks test between year 2013 and 2014

Thermodynamics Topics	Asymp. Sig. (2-tailed) p-value
Thermodynamics and the world' 13_Thermodynamics and the world' 14	.410
Laws of Thermodynamics' 13_Laws of Thermodynamics' 14	.003
Thermodynamics cycles' 13_Thermodynamics cycles' 14	.041

*p <0.05.



with reviewed projects on Second Law of Thermodynamics, 8 students with creative projects on Heat and 10 students with projects on Entropy. Results show that, for example, students who reviewed the concept of First Law of Thermodynamics in their creative project were more likely to solve the Heat-related problems correctly ($M = 7.18, SD = 3.64$) than problems related to the Second Law of Thermodynamics ($M = 6.04, SD = 3.60$) and Entropy. The plot of means of the four concepts discussed in the example above appears as shown in Figure 8 below.

There were no statistically significant differences between group means as determined by one-way ANOVA ($(3, 62) = .298, p = .83$). No statistically significant difference was detected across the other three topics; therefore, the results did not corroborate our second hypothesis. Table 4 combines the descriptive statistics and the One-Way ANOVA analysis of creative projects on 1st, 2nd Law of Thermodynamics, Heat and Entropy.

Table 4. Descriptive statistics and one-way ANOVA for four concepts.

Concept	M	SD	N	DF	Sum of Squares	F	Sig.
1 st Laws of Thermodynamics	6.75	3.45	20	3	10.533	0.298	0.83
2 nd Laws of Thermodynamics	6.04	3.60	24	3	2.262	0.825	0.49
Heat	7.18	3.65	8	3	35.247	0.098	0.96
Entropy	6.25	2.70	10	3	17.579	0.376	0.77

* $p < 0.05$



To address the study's third hypothesis, at the end of the two semesters all participating students were asked in a survey to share their perceptions of the creative project. In both semesters, students overwhelmingly found creating a creative format entry stimulated their thinking, clarified concepts of thermodynamics, and increased their confidence in applying concepts of thermodynamics in real life. The students claimed they would appreciate and welcome similar creative projects in future engineering fundamental courses. In the fall of 2013, 96% of the students thought the creative project stimulated their thinking and 85% thought the project clarified their concepts of thermodynamics. In 2014, 81% of the students thought the creative project stimulated their thinking and 81% thought the project clarified their concepts of thermodynamics. Table 5 in Appendix A contains the student self-reported outcome measures and descriptive statistics.

DISCUSSION

This study focused on the impact of creative presentations on performance on a final exam question related to the students' creative presentation topic. While this instructor also employed an existing evaluation tool pre/post (*Thermal and Transport Concepts Inventory*, Miller, Streveler, Nelson, Geist, and Olds, 2005), the results of this particular study show that the creative assignment made the learning process more visible and measured the learning of thermodynamics in a different way. The presentations were high-energy events in rhythms and rhymes, as students presented their creative takes on Thermodynamics. What we found was beyond the fact that they "loved" these projects. Students indicated the participation in the contest helped clarify course concepts and increased their appreciation of the Laws of Thermodynamics and the engineering profession. The students also claimed the contest encouraged them to think about the concepts in novel ways and stimulated their creativity.

The study results also show evidence for the benefits of our creative project. These results corroborate our first hypothesis, suggesting that if students choose a creative medium to present concepts from Thermodynamics they attained significantly better scores than the median score, as shown from performance on the final exam. A plausible explanation is that working on the creative entries encouraged students simply to spend more time studying a contest-related concept, resulting in increased performance on that particular concept.

Our second hypothesis was not corroborated. However, even with the insignificant difference between performance on a final exam question related to students creative project, students who's creative projects were related to one of the following concepts - 1st, 2nd Law of Thermodynamics, Heat and Entropy, scored higher than their peers who did not develop a creative project for the same



concept. For example, students who worked with the First Law of Thermodynamics scored higher on both First Law and Heat-related problems. The same was the case for Second Law and Entropy-related problems. This is plausible given that these concepts are theoretically connected. Furthermore, it is plausible that students chose to work with concepts with which they were already comfortable and the enhanced performance on the final exam and the project are both effects of the same cause rather than causally related themselves. Perhaps although students might choose a topic with which they are comfortable, the time devoted to thinking more deeply about it for developing creative product enhances their performance even more. Primarily, we are suggesting that offering engaging activities to learn engineering concepts can potentially strengthen student understanding of these concepts.

Our performance measure is limited because students had a choice in selecting the concept they wished to work with, which reduced our sample size and introduced the possibility of limiting an examination of the effect of the creative projects on students who created entries for concepts that are not very popular. Instructors could decide to randomly assign students to specific concepts to ensure more diversity in terms of material coverage. As Wesselmann et al. noted, instructors could conduct this type of creative assignment in both fully online and hybrid courses by having students upload their creative entries to a class website and then having the class also vote for their favorite entries (Wesselmann et al., 2016). The flexibility of this exercise, coupled with its ease of implementation, makes it an exciting exercise for instructors and students in multiple topic areas, across disciplines or class formats.

CONCLUSIONS

This exploratory study investigated if there is a relationship between students' performance on problems in the course final exam that assessed knowledge on a topic and their participation in developing a creative entry on the topic. Beyond the impact on this group of students in a thermodynamics class, expressing new knowledge creatively demonstrates the "power of artsience . . . [which] introduces a new culture, drives learning, and rewards risk-taking outside a home culture" (Edwards, pg. 172). One of the "new cultures" that future engineers will interact with resides in the humanities and arts. A call for melding the liberal arts and STEM (Ottino and Morson 2016; Bordoloi and Winebrake 2015), effectively making a space for STEAM, can expand "the pool of knowledge from which they draw" (Jackson- Hayes n.p.).

This study of how the course was taught with the creative activities described has confirmed for us importance of introducing a creative approach, one that prepares students for diverse applications. As we begin to consider creative studies a discipline of its own, with



contributions to multiple disciplines, we can agree with Gerald Puccio, chair of the International Center for Studies in Creativity at Buffalo State College: “The reality is that to survive in a fast-changing world you need to be creative. That is why you are seeing more attention to creativity at universities . . . The marketplace is demanding it.” <http://creativity.buffalostate.edu/news/news-creativity-becomes-academic-discipline>

Teaching with a creative activity for two semesters affirmed the study’s evidence that learning concepts in these ways adds value to outcomes. For both authors, teaching with creativity and teaching to foster creativity is always integral to our pedagogies.

Solving both the well-understood problems and the ill-structured problems that make up the core of engineering thinking would be enhanced by multidisciplinary approaches. Our time with students is limited, but we all share the goal of teaching our students to become adept with diverse peoples and ideas, to collaborate, and to contribute more and better ideas through creative ways of knowing in engineering (Bairaktarova and Eodice, 2017).

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AUTHORS



Diana Bairaktarova is an Assistant Professor in the Department of Engineering Education at Virginia Tech and the Director of the Abilities, Creativity, and Ethics in Design [ACE(D)] Lab. Bairaktarova's ongoing research interest spans from engineering to psychology to learning sciences, as she uncovers how individual performance and professional decisions are influenced by aptitudes and abilities, interest, and manipulation of physical and virtual objects. Diana has over fifteen years of experience working as a Design and Manufacturing Engineer. By providing applications of experiential learning in the exploration of new designs that stimulate creativity, Dr. Bairaktarova aims to prepare her students with innovative thinking, helping them to face rapidly changing technologies. Ranging from the exploration of humanly made objects to the education of her students, she strives to enhance her students' ability



to explore and express their creativity, discover their own potential talent, and ultimately to bring their ideas to fruition.



Michele Eodice is the Associate Provost for Academic Engagement and Director of the OU Writing Center at the University of Oklahoma. Eodice's ongoing research interests include co-authoring, collaborative writing, adult and higher education, developing faculty writing at universities, and student engagement and learning through writing practices. Eodice has been a director of a writing center and a leader in the field of writing centers for 20 years; she currently serves as editor of *The Writing Center Journal*, the primary research journal of the International Writing Centers Association. Several contributions to collections have expanded a career-long theme of work that combines understanding writing practices and students' learning of writing with collaboration and co-authoring. One chapter, "Creativity in the Writing Center," written with Elizabeth Boquet, appears in a 2009 award winning collection, *Creative Approaches to Writing Center Work*. Her interest in creativity extends to other fields as well, including engineering.



APPENDIX A

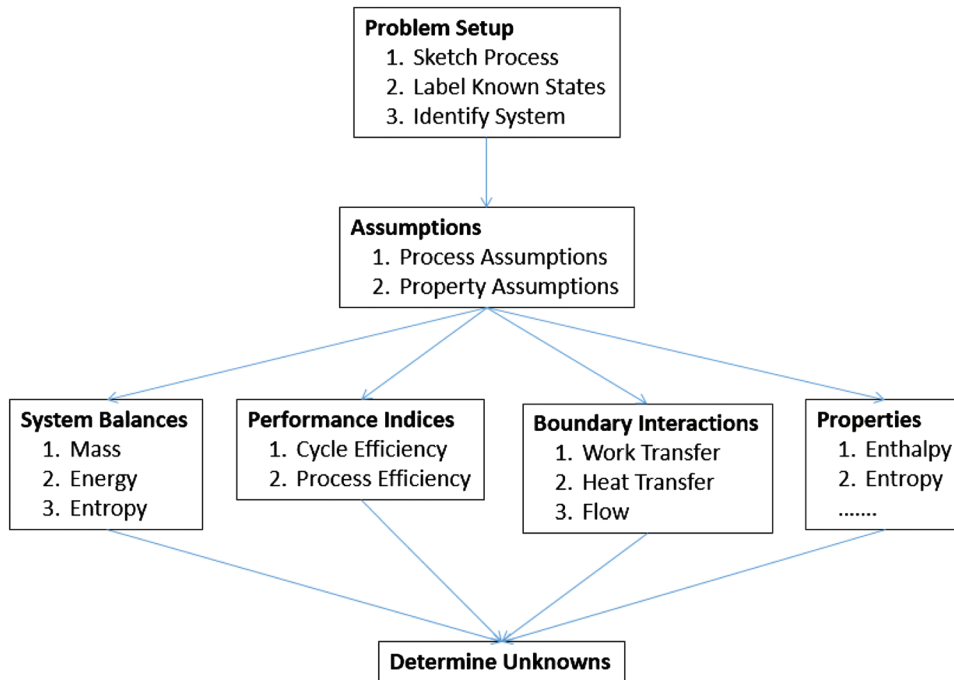
Table 5. Student self-reported outcome measures and descriptive statistics

Contest Evaluation Items	Fall 2013	Fall 2014
The creative assignment stimulated my thinking.	$M = 4.30 (SD = 1.03)$	$M = 4.54 (SD = 1.09)$
The music contest provided good examples for clarifying concepts.	$M = 4.03 (SD = 0.89)$	$M = 4.18 (SD = 0.87)$
The music contest encouraged me to think about the course concepts in novel ways.	$M = 4.80 (SD = 1.23)$	$M = 4.33 (SD = 0.84)$
After the music contest, I feel more confident in my ability to apply course concepts to aspects of my real life.	$M = 4.44 (SD = 1.19)$	$M = 4.04 (SD = 1.05)$
The Creative Project gave me a greater appreciation for thermodynamics.	$M = 4.64 (SD = 1.32)$	$M = 4.33 (SD = 0.99)$
The creative project increased my excitement for the course material.	$M = 4.40 (SD = 1.12)$	$M = 4.58 (SD = 1.02)$
Being able to evaluate (and vote) on the appropriateness of each music entry increased my confidence in mastering the relevant course material.	$M = 3.48 (SD = 1.45)$	$M = 3.42 (SD = 1.21)$
I believe that creating an entry for the contest increased my confidence in mastering the relevant course material.	$M = 4.40 (SD = 0.83)$	$M = 4.70 (SD = 0.98)$
I wish other engineering courses had an activity similar to this creative project.	$M = 4.60 (SD = 0.89)$	$M = 4.39 (SD = 0.87)$



APPENDIX B

Thermodynamics Problem Solving Technique



Problem setup	3 point for correctly setup problem	Boundary interactions	3 points
Assumptions	1 point for correctly made assumptions (.05 for each assumption)	Properties	1 point
System Balance	1 point	Determine unknowns	1 point
Performance indices	1 point		