YEAR TWO: ANALYSIS OF 3D TECHNOLOGY IMPACT ON STEM BASED COURSES; SPECIFICALLY INTRODUCTION TO ENGINEERING COURSES

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Abstract

The impact of new technologies on teaching and learning engineering is important to study and understand for various reasons, including: (1) use of technology tools by students is widespread, and (2) use of technology tools in primary, secondary, and college classrooms is increasing rapidly as new devices that balance cost, functionality and portability shift the use of computing devices from personal purposes to mainstream course applications, such as with 3D printing, for academic purposes. We will present the results of studying the impact of using one such device, a 3D printer, on students' academic performance via a subset of course objectives for an introductory engineering course. This paper inherently focuses on student perceived value and learning impact (comprehension of learning outcomes). This is the second year in which a set of 3D design projects were assigned to students along with focused activities to gauge differences in comprehension of learning outcomes. Student perceived value of using a 3D printer for a class was also measured, tested and evaluated within a learning environment comprised of 21st century demographics for the Science, Technology, Engineering, and Mathematics (STEM) fields. The effect of a 3D printer in the STEM classroom was focused on two key indicators: 1. The impact of student learning, measured by class assignments, homework, quizzes and exams (variances between the cohorts will be assessed as part of the second and third semester exams) 2. Student perception, measured via a student attitudinal survey (Likert scale) managed through an independent third-party testing entity and completed after 3D printing technology utilization.

The comprehension component assessment of the study focused on three cohorts of students. All cohorts of students were taught the same way from commencement of the semester until the first course exam. This was done to limit and account for the possible variance of class grades. At the beginning of the seventh week, the first 3D project was distributed for the second, third and fourth classes of students. The usage of the 3D printer in class assignments was focused on maximizing the impact of student learning on the following class areas: class assignments, homework, quizzes and exams. Variances between the cohorts will be assessed as part of the second and third semester exams. This research project yielded data in a field that has not been explored in depth within the targeted demographic environment. The complete analysis on comprehension and student perceived value will be analyzed and results obtained will be included within this paper. Additionally, since this is the second year of the study, new data from the 2015 academic year will be included and compared to the previous dataset to discover trends between the three cohorts.

Introduction

Throughout history there have been many attempts to incorporate different technologies in the classroom [1]. When compared, some of these technologies have seen more success than others [2]. The most commonly used classroom technologies are: PowerPoint software [3], computers, chalkboards, web posting of materials, paper handouts, transparencies, laptops, overhead projectors, classroom computers, online course management programs, whiteboards, online discussion groups, document cameras, tablet PCs, streaming videos, clickers, VCRs, Acrobat Connect software, and PDAs [4]. Currently, however, the impact and effects in the classroom of one of the newest technologies available to the consumer and educational markets, the 3D printer, has not been extensively researched [5][6]. While there are ongoing research efforts to measure the impact of 3D printers in the classroom [8], setting up 3D printing services focuses more on a specific area of engineering. This is one of the first research studies done on an engineering class where students are from all the engineering disciplines. This presents a challenge as currently only limited research is being done that focuses on first-year college students in the first year of engineering and science fields where the demographics compare to those found at The University of Texas at El Paso (UTEP). This research specifically focuses on the impact the "3D printer" and "3D printing projects" have on a subset of objectives for a first year engineering class that represents the university demographics [9]. This research will measure students' perceived value of using this technology (specifically the 3D printer) inside and outside the classroom. This type of study has not been previously done given the demographics, content, and subject matter involved. This research provides important information for both the engineering and engineering education fields.

The evolution of classroom technology as a tool is variable and the rate at which it evolves changes from device to device. An example of this type of evolution is the chalkboard. Chalkboards have been around for a long time and have evolved from chalkboards into whiteboards, and then some of the functions of the boards were transferred to projectors and computers, thus evolving into smartboards. [4] Would the new generation of students perceive the impact of a 3D printer as a beneficial tool in their education? This research uses the 3D printer to provide a physical 3D model representation of some the most commonly used concepts in an introduction to engineering course. Some of these concepts are: critical thinking, basic and intermediate computer skills, three- dimensional vectors, computer simulation, systems engineering and systems thinking, time management, research techniques, presentation skills and project management techniques. Will the impact of the use of a 3D printer in the classroom outweigh its cost in this framework? This is one of our primary questions.

Materials and Methods

This research began the summer of 2013 with the design and development of an infrastructure that would support the use of a 3D printer for class projects. It was incorporated as part of the UNIV 1301 Foundations of Engineering classes (3 sections of the same class using the 3D printing technology) beginning the Fall semester of 2014. The classes participating in this initial study consisted of similar enrollment numbers. Class A had twenty-four students and was designated the reference group and did not participate in the use of 3D printers in the class. The first class that did use 3D printers in the class (Class B) consisted of twenty-six students; the second class (Class C) had twenty-two students, and the third class (Class D) had twenty-four students. The study continued in the Fall of 2015. The first 2015 class (Class E) consisted of twenty-nine students, the second class (Class F) had twenty-seven students, and the third class (Class G) had twenty-seven students. Students from both years of the research were enrolled mainly in core curriculum classes such as Foundations of Engineering, Pre-calculus, History, and Political Science. All of the students in these classes were first semester freshmen and the class distribution represents the university demographics [5]. This type of enrollment reduced outside factors that influence student learning and allowed the 3D printer to be one of the few variables.

The teaching materials for the class consisted of a group website created using Microsoft SharePoint, a series of PowerPoint and Keynote presentations, and individual and team quizzes in text format. Also included were several in-class active learning activities focused on engineering design, teamwork, and problem solving. Along with the materials already used for the class, this research included use of five 3D printers. One was the Makerbot Replicator Desktop Printer (fifth generation with a build volume of 25.2cm L x 19.9cm W x 15.0cm H and capable of printing 456 cubic inches). The other four were Ultimaker 2 Desktop Printers (with build volume of 22.3cm x 22.3cm x 30.5cm). Both printers, the Makerbot and the Ultimakers, were rated in the top 10 of the best 3D printers. [7]

The experiments conducted to analyze student perceived value and learning impact are detailed below. As an overview, following is how the experiments were conducted. During the first year of the study academic learning performance in all four classes was compared to determine the learning impact on students when the 3D printer was introduced. This was done after teaching the same class content to all four classes. For the second experiment, a post-attitudinal survey was given to all of the students of the classes that used the 3D printer. This same procedure was followed for the second year of the study.

Training was an integral part of the student project as was attending different technology workshops provided by the Learning Environments (LE) area within the Academic Technologies (AT) department at UTEP. LE works directly with students and faculty to research and prototype technology in educational spaces. In addition, students were given a web space and training in different types of software (iWeb, iMovie, Inventor Fusion, and Thinker Cad) to present their projects and their progression.

UNIV 1301: Foundations of Engineering Class Format

UNIV 1301: Foundations of Engineering is a 3-credit hour face-to-face class that meets three hours per week. An attendance policy is enforced which allows no more than three absences for the entire semester. The grading areas of the class include homework, quizzes & projects, exams I and II, and a student presentation. The material covered in the class focuses on these four areas equally: basic engineering and science concepts, math applications in engineering, entering student life activities (with focus on the engineering department), and engineering professions. The material presented in class is divided into three segments of six weeks each. An examination is given at the end of segment 1 and segment 2. After the last six weeks a comprehensive final exam is also given to all students. During both years of the 3D technology impact study, the 3D printing projects and exercises were only included during the second six weeks of the course.

Class Content Research - First Six Weeks

For the first six weeks of the course for both years of the study, the first part of the experiment was to teach the same content to the seven classes without the 3D printer projects and then compare their performance. This was done to generate a baseline for the differences in comprehension of the same content between the classes. At this point, the class where the 3D printer was not used will be referred to as "Class A" and will be used as the reference for both years. The classes where the 3D printer was used in the first year will be referred to as "Class B", "Class C" and "Class D" and the classes where the 3D printer was used in the second year will be referred to as "Class E", "Class F" and "Class G". As a precautionary measure to prevent students from passing-on exams from one year to the next, students were not allowed to keep their exams and the order of the questions was changed. A grading scale of 0 to 100 was used for the exams. The average of Class A on exam one was 77.9. For year one of the 3D printing pilot, the average of Class B on exam one was 82.5. The average of Class C on exam one was 85.0. The average of Class D on exam one was 72.31. All of these results are shown in Table 1. For year two of the 3D printing pilot, the average of Class E on exam one was 81.97. The average of Class F on exam one was 82.63. The average of Class G on exam one was 66.38. On year two of the study Class A was outperformed by Class E by 4.04 points on average, Class F outperformed Class A by 4.7 points and Class G was outperformed by Class A by 11.55 points. All of these results are shown in Table 2. These results are examined in the Discussion section.

		Research Results of 2014			
	Baseline Class				Difference from Class A
	Class A	Class B	Class C	Class D	Class B, Class C, Class D
Exam 1	77.93	82.50	85.00	73.31	+4.57, +7.07, -5.62
Exam 2	59.70	65.50	86.83	79.21	+5.8, +27.13, +19.51
Final Average	81.08	82.90	85.50	78.60	+1.82, +4.53, -2.48

Table 1. Average academic Performance 2014.

		Research Results of 2015			
	Baseline Class				Difference from Class A
	Class A	Class E	Class F	Class G	Class E, Class F, Class G
Exam 1	77.93	81.97	82.63	66.38	+4.04, +4.7, -11.55
Exam 2	59.70	78.74	82.30	73.59	+19.04, +22.6, +13.89
Final Average	81.08	83.19	86.47	74.89	+2.11, +5.39, -6.19

Table 2. Average academic Performance 2015.

Class Content Research - Second Six Weeks

For the second six weeks all of the students in Classes B, C, D, E, F, and G began working on a 3D printer design of a bridge using the same concepts as were introduced in Class A. Class A continued the course without any 3D printer exercises. Students in Classes B, C, D, E, F and G used the class website to download class materials and upload assignments, among other things. Several of these assignments included drafts of 3D original designs and reports on the progress of the 3D design project. During the second six weeks of the 2014 investigation the **average on exam 2 for Class A was 59.7; the average for Class B was 65.50, the average for Class C was 86.83 and the average for Class D was 79.21. Class D outperformed Class A by 19.51 points; Class C outperformed Class A by 27 points, and Class B by 5.8 points on average**. During the second six weeks of the 2015 investigation we continued to use the same Class A as the reference and the **average on exam 2 for Class A was 59.7; the average for Class E was 78.74, the average for Class F was 82.30 and the average for Class G was 73.59. Class G outperformed Class A by 13.89 points; Class F outperformed Class A by 22.6 points, and Class B by 19.04 points on average**.

Experiment 2 – Student Perceived Value

At the end of the semester for both years, an attitudinal survey was administered to each of the classes using 3D technology. The survey was administered at the 16-week mark (end of the semester). The survey administrators were independent from the instructor and no feedback was given to the instructor at any point in time while the class was in session. To avoid any bias, the instructor was able to see the results only after the course concluded and final grades had been submitted. After the class concluded the attitudinal surveys were analyzed and the results can be found in the Results section.

Results

Data from year one is shown in Table 1. It shows the results of the class performance presented as an average for each class on each of the exams administered during the semester, along with the final course average. Figures 1, 2 and 5 show the grade distribution of the courses on all three exams in an overlapping manner to facilitate the comparison. Data from year two is shown in Table 2. It shows the results of the class performance presented as an average for each class on each of the exams administered during the semester, along with the final course average. Figure 5 shows the distribution of the students' answers before and after finalizing the 3D printing projects on the first year of the investigation.

These results and their impact are discussed extensively in the Discussion section. Figures 3 and 4 display several important trends that were discovered in year one using this survey instrument. The questions in Figures 5, 6, 7 and 8 are not all the questions asked of the students, but are the ones that show the greatest impact by the project. For a complete listing of the survey instrument please visit http://3dprint.at.utep.edu

Figure 5 shows four sample questions presented to the students after the semester ended. These four questions are the ones in which more than 70% of the students agree and strongly agree on the answer. Due to this fact these questions where cataloged as higher impact for year one of the study. For year two of the study Figure 7 and Figure 8 show the questions of high impact with a positive rating of 80% or higher.

Discussion

The first result discussed is the fact that Classes B, C, D, E, F and G performed better than Class A during the second 6 weeks of the course when the 3D technology projects were assigned. After a more in-depth analysis of these results it can be seen that on the first exam Class B performed 4.57 (four and a half) points **above** Class A, Class C performed 7.07 (seven) points **better** than Class A, and Class D performed 5.62 (five and a half) points **below** Class A for year one. For the second year of the study Class E performed 4.04 (four) points **above** Class A, Class F performed 4.7 (rounding to a five) points **better** than Class A, and Class G performed 11.55 (eleven and a half) points **below** Class A. If everything is maintained constant, it would be expected that for the second six weeks Class B would perform 4.5 (four and a half) points above Class A; Class C would perform 7.0 (seven) points above Class A; and Class D would perform 5.5 (five and a half) points below Class A for the first year. For the second year if everything is maintained constant it would be expected that: Class E would perform 4.0 (four) points above class A, Class F would perform about 5.0 (five) points above Class A and Class G would perform about 11.5 (eleven and a half) points below Class A. Analyzing the rest of the results in Table 1 and Table 2, it can be clearly seen that Class B has outperformed Class A in exam II by 5.80 points, Class C outperformed Class A by 27.13 points, Class D outperformed Class A by 19.51 points, Class E has outperformed Class A in exam II by 19.04 points, Class F outperformed Class A by 22.6 points, Class G outperformed Class A by 13.89 points. If the 4.5 (four-point five), 7.0 (seven-point) and the -5.5 (negative five and a half-point) difference without technology were taken into account for exam II, the net difference would be around **1.23 improvement points** for Class B, **20 improvement points** for Class C, and **25 improvement points** for Class D. Applying the same comparison as in year one to year two of the investigation, the net differences would be and **improvement** for Class E of 15.0 (fifteen) points, an **improvement** for Class F of 18.0 (eighteen) points and for Class G an **improvement** of 25.0 (twenty-five) points. This could be attributed to specific topics where the 3D technology was used extensively during the second six weeks. Topics such as: 2D and 3D vectors, area and volume calculations, unit conversions and material density calculations that were tested during exam II. Figures 1 and 2 describe the student grade letter percentage distribution of exams I and II for year one of the study. Figures 3 and 4 describe the student grade letter percentage distribution of exams I and II for year two of the study. These will be shown in color to showcase the latest results.

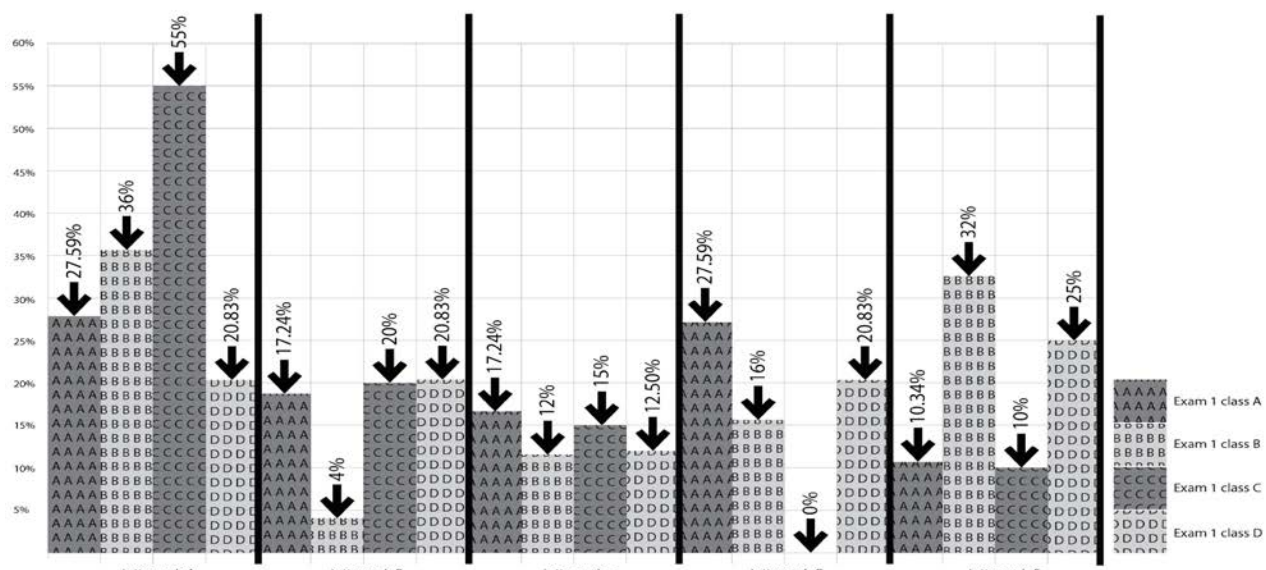

Figure 1. Year one exam 1 student percentage grade distribution comparison

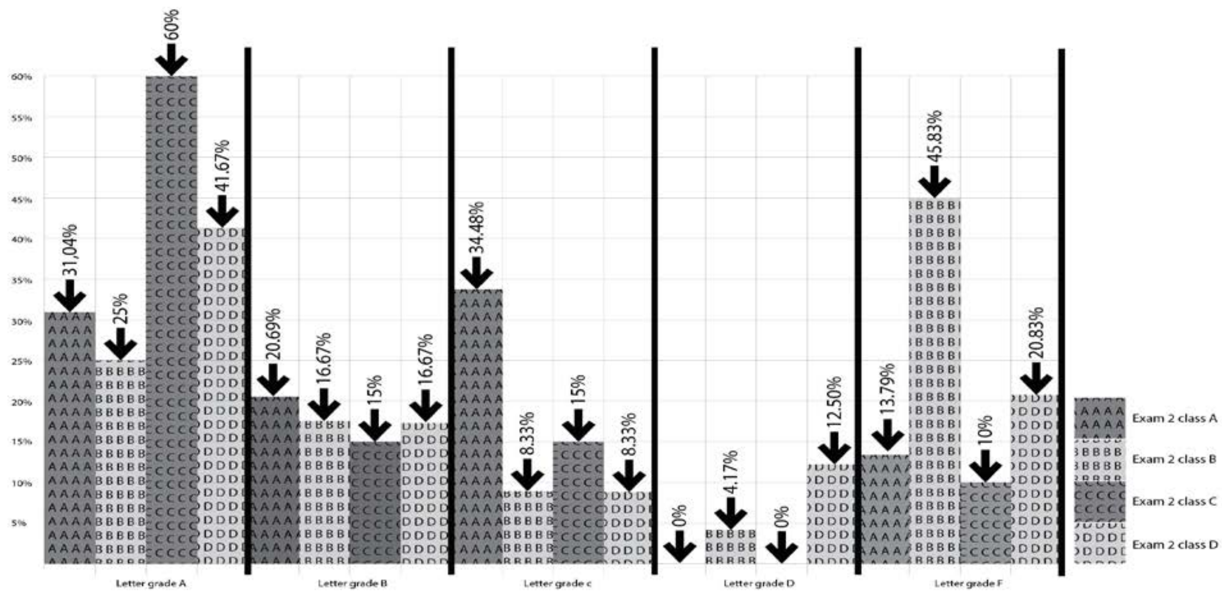

Figure 2. Year one exam 2 student percentage grade distribution comparison.

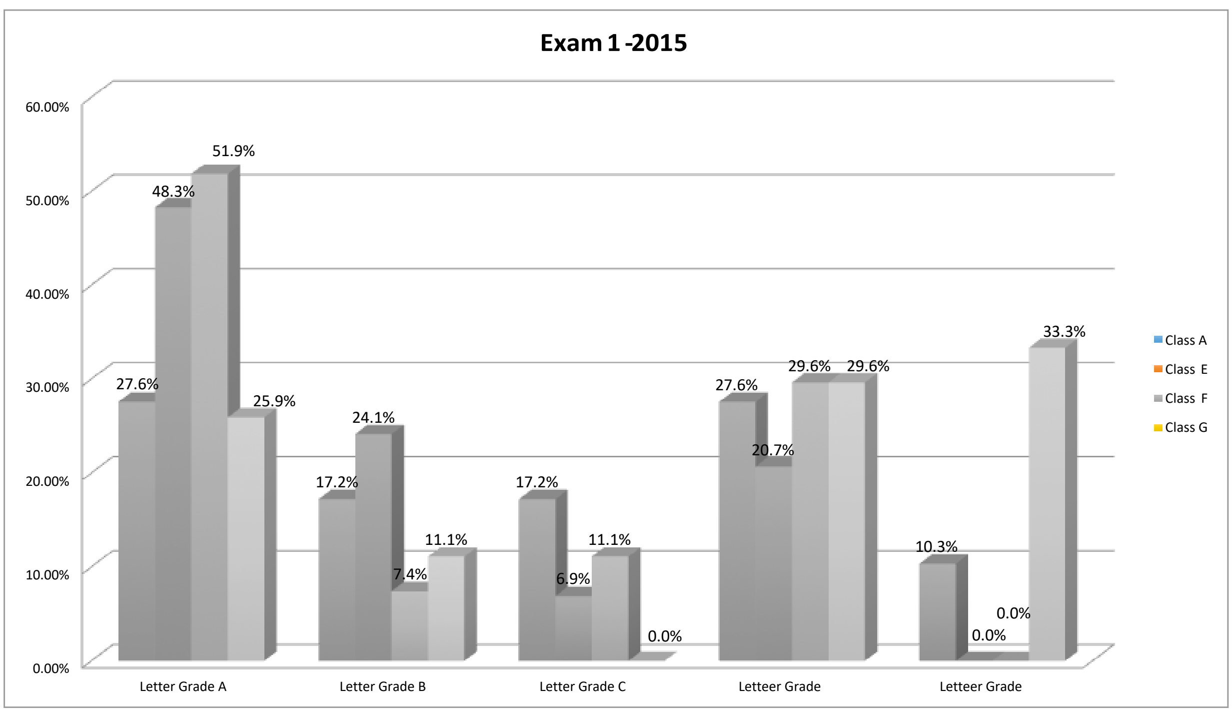

Figure 3. Year two Exam 1 student percentage grade distribution comparison.

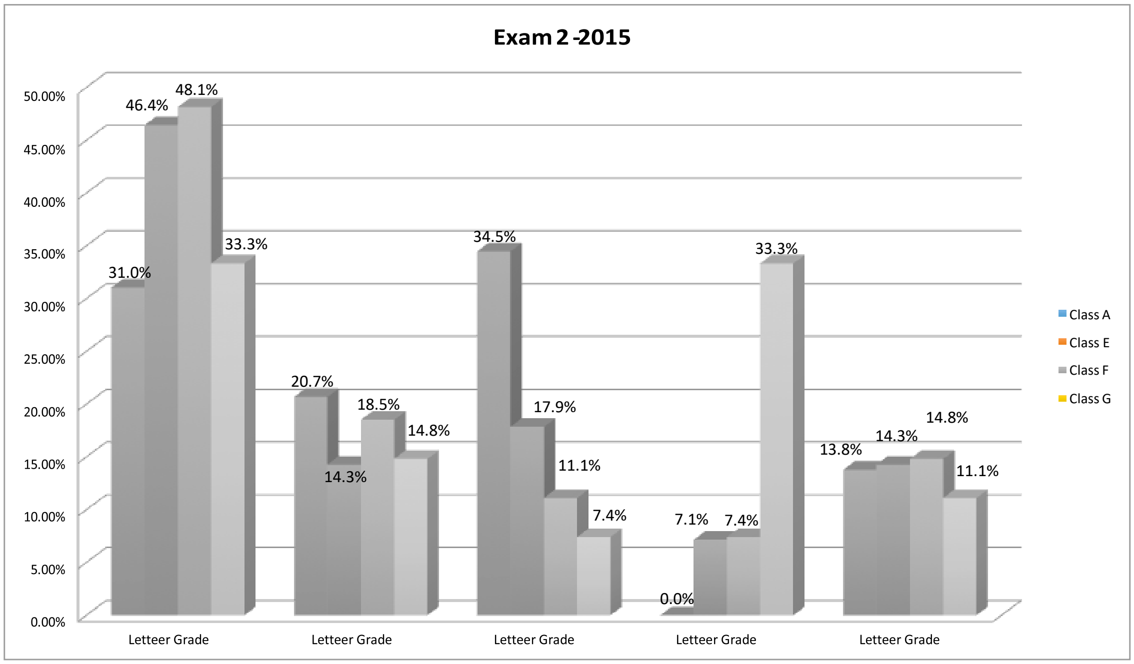

Figure 4. Year two Exam 2 student percentage grade distribution comparison.

After analyzing the results of the attitudinal survey for both years of the study, it can be seen that the students perceived an increase in knowledge. The results displayed in Figure 5 for year one and Figure 7 for year two support the statement that the 3D technology project also had a positive impact on other areas such as basic computer software applications, engineering innovation, engineering disciplines, and project management principles. Figure 5 and Figure 7 also show that the students increased their interest in 3D printing and design (question 40). The four questions shown in Figure 5 represent the areas in which this 3D project had the bigger impact according to student perception.

The students see the impact of the 3D technology printing and design projects as a positive factor in their learning. The results displayed in Figure 5 & 7 support this statement. This also holds true for year two of the investigation. The percentages on the same questions increased as can be seen in Figure 7 and Figure 8. The change in the students' perception of how much they learned dramatically shifted towards the above average and well above average categories after the implementation of the 3D technology project.

Another set of questions in which the majority of the students agree on their perceived learning is shown in Figure 6 for the first year and Figure 8 for year two. In this set of questions the agreement of the students was higher than 60% and lower than 70% for year one and between 80% and 82.6% for year two. Here we can see that the 3D technology project had a high impact in the areas of time management, engineering career awareness and planning, research methods and techniques, critical thinking concepts, and unit systems and conversions. From previous research we have confirmed the fact that engineering students with the demographics of UTEP prefer a class that uses technology.

Finally, from the attitudinal survey, as a whole, the majority of the students were actively engaged in the different activities required to complete the 3D printing technology project during year one and year two. Comments like the following were written on the open-ended questions of the survey:

- Question 48. What new technical and engineering concepts did you learn from this project?
    - o "I learned how to use the software for the 3d printer and how to develop a design."
    - o "I learned about the concept of weight distribution in structures."
    - o "I learned on how to create a 3D design

using the inventor"

- Question 54. What was your favorite part about 3D bridge project?
    - "Designing it and seeing a final product."
    - "My favorite part was to ACTUALLY WATCH MY FINAL DESIGN PRINTED OUT!"
    - "how the 3d printer actually works."

From these two years of analysis it can be can determined that new technologies can be used to engage students in learning and that students not only like the usage of technology in their coursework but also prefer courses that use cutting-edge technologies in the classroom. Similar trends can be found on other 3D printing articles in online magazines [11]. As shown in questions on Figures 5 ,6, 7 and 8, we can see a pattern emerge. Eight of the questions from year one that were rated high repeated as rating high in year two of the study with even higher approval rates. Questions 40 and 14 were ranked among the top 3 positively rated for both years. This shows how the 3D printing project helped students by increasing their interest in 3D printing and design as well as increasing their skills in 3D design and computer skills.

14.After finishing this 3D Printing and design project, I have increased my knowledge in the area of basic computer software application skills (e.g. MS Office Suite, Matlab, 3D design software, etc.)?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5	6	9	31	17

21.After finishing this 3D Printing and design project, I have increased my knowledge in the area of introduction to engineering disciplines, engineering innovation (engineering design)?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
8	5	7	29	19

25.After finishing this 3D Printing and design project, I have increased my knowledge in the area of project management principles (teamwork, cost analysis, etc.)?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5	4	10	29	20

40.After completing the project did your interest, in 3D printing and design increase?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
7	3	4	29	25

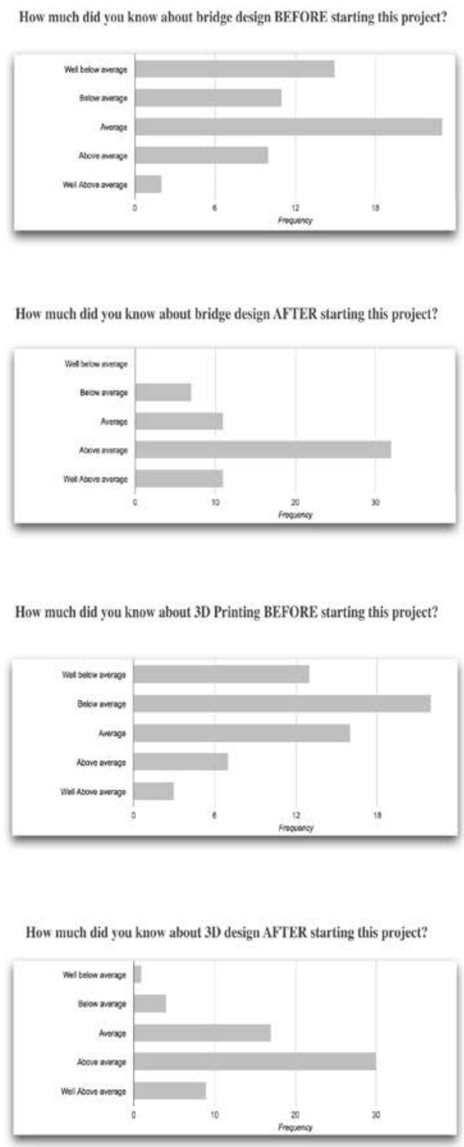

Figure 5. Year one Multiple-choice section of survey on the left (n=68) and Section of pre- survey and post-survey on 3D printing and bridge design on the right (n=68).

11. After finishing this 3D Printing and design project, I have increased my knowledge in the area of time management?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5	7	12	25	19

13. After finishing this 3D Printing and design project, I have increased my knowledge in the area of engineering career awareness and planning?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5	9	7	30	17

15. After finishing this 3D Printing and design project, I have increased my knowledge in the area of research methods / techniques?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
6	2	17	28	15

19. After finishing this 3D Printing and design project, I have increased my knowledge in the area of critical thinking concepts (problem solving)?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
6	7	10	28	17

26. After finishing this 3D Printing and design project, I have increased my knowledge in the area of unit systems and conversion?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5	6	15	28	14

37. After finishing this 3D Printing and design project, I have increased my knowledge in the area of access to engineering professionals/industry?

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
5	5	17	28	13

Figure 6. Year one multiple-choice section of survey on knowledge gained (n=68).

4. After finishing this 3D printing and design project, I have increased my knowledge in the area of basic computer skills.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	0	8	42	24

Average score: 4.173

14. After finishing this 3D printing and design project, I have increased my knowledge in the area of basic computer software application skills (e.g. MS Office Suite, Matlab, 3D design software, etc...).

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
3	0	8	49	15

Average score: 3.973

40. ALMOST DONE! After completing this project my interest in 3D printing and design increased.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
3	1	8	29	34

Average score: 4.2

2. After finishing this 3D printing and design project, I have increased my knowledge in the area of study skills planning/organization.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	1	10	45	18

Average score: 4.04

13. After finishing this 3D printing and design project, I have increased my knowledge in the area of engineering career awareness and planning.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
2	4	7	43	19

Average score: 3.973

Figure 7. Year two multiple-choice section of survey on knowledge gained with a positive rating of over 82.6% and up to 88% (n=75).

21. After finishing this 3D printing and design project, I have increased my knowledge in the area of introduction to engineering disciplines, engineering innovation and engineering design.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
2	1	10	43	19

Average score: 4.013

25. After finishing this 3D printing and design project, I have increased my knowledge in the area of project management principles (teamwork, cost analysis, etc...).

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
2	2	9	41	21

Average score: 4.027

11. After finishing this 3D printing and design project, I have increased my knowledge in the area of time management.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
3	2	10	39	21

Average score: 3.973

19. After finishing this 3D printing and design project, I have increased my knowledge in the area of critical thinking concepts (problem solving).

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
2	4	9	48	12

Average score: 3.853

25. After finishing this 3D printing and design project, I have increased my knowledge in the area of project management principles (teamwork, cost analysis, etc...).

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
2	2	9	41	21

Average score: 4.027

Figure 8. Year two multiple-choice section of survey on knowledge gained with a positive rating between 80% and 82.6% (n=75).

Conclusion

Finally, this study was conducted in a framework that represents UTEP demographics in an entry-level engineering course. From this study we can conclude that the class average increased in the three classes that implemented the 3D technology project during year one of the study and the trend was maintained and increased for year two of the study. A strong argument can be made that because Class B started 4.5 points above Class A, the absolute impact is an increase of 1.5 points on exam 2 for Class B, 20 points for Class C, 25 points for Class D, 15 points for Class E, 18 points for Class F and 25 points for class G in comprehension of learning outcomes. This is attributed to the applications that were used in the 3D technology project that include 2D and 3D vector analysis, unit conversion, area and volume calculations, and engineering design method and density calculations. Students' perceived value and learning impact of having used a 3D printer for the course was very positive for both the first and second year of the ongoing research.

In summary, the use of the 3D printer increased the students' academic performance when its use was closely tied to the class content. As a bonus, there was a highly positive impact of the students' perceived value of using a 3D printer in the classroom, which in turn positively affected the classroom environment [10] as shown in other scholarly articles [12]. For year one, the price of the printer was $2300 USD and it impacted more than 70 first year engineering students, the majority in a positive way. The 3D printer will continue to be used for subsequent classes. Therefore, as more and more students use it, the cost per student will continue to decrease (at this point it is about $32.85 USD per student). For year two, four printers were purchased (the total cost of the 4 printers was $9996.00) and used not only by the classes mentioned in this research but also by other 3 classes supporting a total of 166 students. The total material used to print all of the 3D designs for all 3 classes adds up to 1404.72 grams of PLA (each 1000 gram spool of PLA cost $40). The cost of this project per student has come up to (9996.00+80.00)/166 = $60.70 per student. As more and more students use these printers the cost per student will keep decreasing.

Table 3 and Table 4 shows the amount of PLA material used for each of the designs, the time it took to print each and the actual cost per design based on the material used.

Future Work

More research needs to be done on the lasting impacts of the concepts taught during the second six-week portion of this study (i.e. does the perceived value of a 3D printer on specific course objectives substantially impact content retention of those concepts later in the students' academic career?) As we progress into the third year of this ongoing research, some of the questions to be addressed include long-term analysis of the following:

- Does engaging a student with technology on a difficult learning objective give them better mastery of that content area later in the academic career?
- How does changing the perceived value of a course with technology impact the long-term perception of students' value of essential learning objectives and their performance and mastery of them throughout their career?
- Does motivating students early on with technology such as 3D printers increase the chances of them graduating due to positive first semester engagements with the content?

Future work planned for this ongoing research should expand to the following areas: 1) implementation of electric conductive materials for the design; 2) acquisition of another printer with dual extruder capabilities to evaluate print designs integrating electric flow. 3) The implementation of the 3D printer across different engineering areas in higher-level engineering classes to benefit more students from this experience.

Table 3. 3D team designs characteristics Year One					
Bridge Design Project (PLA 1.75mm cost=$30.00 for 1000 Grams)					
Instructor	**Team Name**	**Build Time (Hours)**	**Resolution**	**Material Used (Grams)**	**Cost per design**
Instructor 1	The Beatles	8h 13m	0.2mm	89.03	$2.67
Instructor 1	Bridge Team	8h 47m	0.2mm	83.6	$2.51
Instructor 1	3D Bridge	7h 26m	0.2mm	78.68	$2.36
Instructor 2	Bridge 2	6h 16m	0.2mm	66.89	$2.01
Instructor 2	Bridge innators	4h 44m	0.2mm	47.31	$1.42
Instructor 2	Epsilon Team	8h 51m	0.2mm	90.98	$2.73
Instructor 2	Final Bridge	7h 52m	0.2mm	82.97	$2.49
Instructor 3	Bridge	4h10m	0.2mm	36.46	$1.09
Instructor 3	Epsilon Bridge	8h 45m	0.2mm	89.26	$2.68
Instructor 3	Team 3	2h 50m	0.2mm	26.52	$0.80
Instructor 3	The Trolls	11h 38m	0.2mm	144.83	$4.34
Instructor 3	Univ Bridge	12h 59m	0.2mm	162.22	$4.87

Table 3. Cost and material used per design for year one of the study.

Table 4. 3D team designs characteristics --- Year Two					
Bridge Design Project (PLA 2.85mm cost=$40.00 for 1000 Grams)					
Instructor	**Team Name**	**Build Time (Hours)**	**Resolution**	**Material Used (Grams)**	**Cost per design in US $**
Instructor 1	Build a bridge	3:28	.125mm	29.23	$1.17
Instructor 1	The league final bridge	4:31	.125mm	38.72	$1.55
Instructor 1	Dazzling	3:23	.125mm	40.79	$1.64
Instructor 1	Denominators	4:13	.125mm	37.28	$1.50
Instructor 1	Meza Bridge	5:22	.125mm	46.7	$1.87
Instructor 2	Team 1	4:47	.125mm	46	$1.84
Instructor 2	Team 2	5:30	.125mm	65	$2.60
Instructor 2	Team 3	6:30	.125mm	65	$2.60
Instructor 2	Team 4	3:05	.125mm	28	$1.12
Instructor 2	Team 5	3:50	.125mm	40	$1.60
Instructor 2	Team 6	6:40	.125mm	67	$2.68
Instructor 2	Angel-Rgz	6h	.2mm	47	$1.88
Instructor 3	Classified Final Design	2h	.2mm	31	$1.24
Instructor 3	Team 2	4h	.2mm	30	$1.20
Instructor 3	Los Perezosos	2:24	.2mm	17	$0.68
Instructor 3	NWA Final bridge	2:37	.2mm	20	$0.80
Instructor 3	The A team Final design	4:30	.2mm	36	$1.44
Instructor 3	the elite team	4:37	.2mm	37	$1.48
Instructor 4	WhiskyTangoFoxtrot	14:38	.125mm	166	$6.64
Instructor 4	Truss_Us	4:23	.125mm	50	$2.00
Instructor 4	Highroll	1:44	.125mm	17	$0.68
Instructor 4	Los Cuervos	1h	.125mm	11	$0.44
Instructor 4	Bridge of Deutschland	6:30	.125mm	70	$2.80
Instructor 4	TheMiners	2:46	.125mm	29	$1.16
Instructor 5	Thug Nasties 3D Bridge	6:00	.125mm	66	$2.64
Instructor 5	Group Bridge	10h	.125mm	100	$4.00
Instructor 5	Bridge Truss Suspension	3:00	.125mm	30	$1.20
Instructor 5	Epic Bigery Hango	8:10	.125mm	83	$3.32
Instructor 5	Bridge Printable	5:10	.125mm	61	$2.44

Table 4. Cost and material used per design for the second year of the study.

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Biographical Information

Prof. Oscar A. Perez received his Masters and PhD. in Electrical Engineering from the University of Texas at El Paso with a special focus on data communications and control systems. He has been teaching the Basic Engineering (BE) – BE 1301 course for over 9 years. Lead the design for the development of the new Basic Engineering course (now UNIV 1301) for engineering at UTEP: Engineering, Science and University Colleges. Oscar has developed new courses, including UTEP technology & society core curriculum classes specifically for incoming freshman with a STEM background. He has thirteen years of professional experience working as an Electrical and Computer Engineer designing, testing and providing technical support to faculty and students utilizing state of the art technology in classrooms and auditoriums. He currently works on maintaining, upgrading and designing the classroom of the future at UTEP. His research areas are in Control Systems, Networking, App Development, Cyber security, 3D Printing and Engineering Education.

Pedro Espinoza worked in the manufacturing industry as a Quality Control Engineer for some years before acquiring his current position as an Instructional Technologist at the University of Texas at El Paso (UTEP). He received his Bachelor of Science degree in Electrical Engineering and a Master of Science in Engineering with a concentration in Engineering Education from UTEP.

Mr. Hugo Gomez works as an Instructional Technologist at the University of Texas at El Paso. Hugo provides workshops to over half of the student population at UTEP and as such, has been instrumental in providing the behind the scenes support to all these courses. Mr. Gomez collaborates in the Learning Environments team to explore and implement new educational strategies in the classroom. Mr. Gomez teaches UNIV1301 Foundations of Engineering, were students learn academic, personal and engineering skills, among many other abilities that help them understand their opportunities and responsibilities as engineering students..

Mike Pitcher is the Director of Academic Technologies at the University of Texas at El Paso. He has experience in learning in both a traditional university program as well as the new online learning model, which he utilizes in his current position consulting with faculty about the design of new learning experiences. His experience in technology and teaching started in 1993 as a student lab technician and has continued to expand and grow over the years, both technically as well as pedagogically. Currently he works in one of the most technically outstanding buildings in the region where he provides support to students, faculty, and staff in implementing technology inside and outside the classroom, researching new engineering education strategies as well as the technologies to support the 21st century classroom (online and face to face). He also has assisted both the campus as well as the local community in developing technology programs that highlight student skills development in ways that engage and attract individuals towards STEAM and STEM fields by showcasing how those skills impact the current project in real-world ways that people can understand and be involved in.

Randy Anaya, Instructional Technologist at the Graphic Design with a minor in Multimedia design from the Universidad Auto´noma de Ciudad Juarez, Mexico. Received a BA in Media Advertising at UTEP and is currently enrolled as a Master of Interdisciplinary Studies with an emphasis on the use of art and technology in teaching and learning. He works on research and development of applying the creative process to workshops, trainings and student engagement. Currently doing extensive research and deployment of emerging technologies to redefine the classroom, mentoring and excellence through student interaction.

Herminia Hemmitt is part of the Learning Environments team in Academic Technologies at The University of Texas at El Paso. She is responsible for coordinating classroom technology upgrades and implementations to ensure project deadlines and anticipated goals are met. Her educational background in organizational and corporate communication is utilized in consultations with faculty and staff about their learning environments in order to correctly match them to appropriate learning spaces or adapt existing spaces to meet their pedagogical and technological needs. Her focus is on the specific user to make sure that classroom needs, technical needs, and/or event needs are met.

Mr. Hector Lugo works as a Student Technology Success Coordinator at The University of Texas at El Paso. He holds a B.S. in Electrical Engineering. He is currently enrolled as a Master of Science with a Major in Electrical Engineering. His motivation and passion pushes him into research in wireless communication, especially in Bluetooth Low Energy and Near Field Communication as well as building projects and fostering innovation with faculty and staff members. As part of the Learning Environments division, the idea to develop, oversee and assess engaging students to expand their knowledge and creativity by innovating new technologies application for Engineering Education is currently under way to engage the university and the community. Concluding, Mr. Lugo’s ambition is to encourage students to focus in science, technology and engineer abilities in order to expand their professional potential.