Engineering Technology Students Response to Hands-on Fluid Power Exercises

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Abstract: Hands-on interventions have been the focus of many studies; however, they frequently are not done using a population of students involved in active learning. Engineering technology programs are established with the premise that the program will encourage hands-on exercises, in field experiences, and contact with those that have experience in the field. These researchers work with engineering technology students throughout the academic year, some of them have experience in other programs such as engineering, mathematics, and business. They find the contrast between these groups of students often remarkable. Some studies have focused on the cognitive development of this population, others have focused on survey response that includes student or graduate introspection regarding their education and career path. Few focus on how the students respond to short, hands-on tasks involving the use of existing skills, and those they acquire in class. This study presents a set of exercises to students and analyzes the level of engagement, interest, and knowledge gain by asking them to carefully consider the answers to three questions and then respond to those questions. The researchers focus on the qualitative and quantitative answers, as well as student interaction following the exercises. Purdue Polytechnic is one of Purdue's University Colleges and has 9 remote locations spread across the state in addition to main campus. Students located at main campus tend to be traditional students that matriculate immediately after high school graduation, while those at the remote campus' are more likely to matriculate a year or more after high school graduation. The interactive hands-on exercises were tested on students located in one of the remote sites and the results are compared to other remote sites and to the main campus, as well. These groups also are different in size ranging from a few students to nearly 100. The data in this study is analyzed as an aggregate and as separate locations. The researchers find that these students have more intuition to solve problems, as noted by past research on this population, done in a different manner.

Index Terms: Active Learning, Performance Comparisons and Improvements, Student-Centered Learning.

I. INTRODUCTION

Purdue Polytechnic has one main campus and nine other remote locations spread over the state of Indiana. The main campus mainly hosts traditional students who matriculate after graduating from high school. The remote locations focus on students already working in industry as full time employees or who choose to return to college after a gap of time following high school graduation. Applied Fluid Power "MET23000" is a required course in the mechanical engineering technology (MET) programs. The course learning outcomes (CLOs) for this course are as follows which are used to comply with ABET curriculum standards [1]:

1. Design fluid power systems with off the shelf components.
2. Analytically analyze fluid power systems for proper operation.
3. Demonstrate understanding of operational theory of pressure vs. flow relationships in hydraulic systems.
4. Demonstrate understanding of operational theory of pressure vs. flow relationships in pneumatic systems.
5. Demonstrate understanding of application of the conservation of energy equation to fluid power systems.
6. Demonstrate the operation and function of working fluid power systems.
7. Demonstrate application of compressible and incompressible fluids in dynamic and static fluid power systems.
8. Demonstrate conventional solenoid control valve vs. servo control valve technology application to motion control circuits.
9. Use application software for analyzing, documenting, and presenting the results of technical work.

The course is traditionally designed and taught to have approximately 10 predetermined labs at the main campus and other remote locations. The main campus and other remote locations share the same CLOs. In addition to the predetermined labs, a set of hands-on exercises and interactive activities were applied at one of the remote campus locations during Spring 2017. The set of exercises and hands-on activities are summarized using 5 approaches/categories to insure an enhanced analysis. Most of the approaches were repeated with the intent of improving student performance. The five approaches are listed below along with the predicted outcome that relates to the above CLOs:

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Table 1. Used Hands-On Approach Activities and Their Link to CLOs

	Approach	Link to Learning Outcomes
1	Lecture: Distributed lecture materials with a set of equations to students and provide time to read. Students were arranged in groups of 3 with the middle student reporting and taking notes while the three were discussing. The instructor asked questions and randomly picked someone to answer encouraging students to remain engaged and ready to participate.	2, 3, 4, 5, 7, 8
2	Testing material: Students were provided with 5 different pipes and measuring tools. The students were asked to take measurements while the instructor introduced new variables on the white board. Students were asked to report length, diameter, while calculating the velocity, friction loss, and the pressure drop in the pipe.	1, 2, 3, 4, 5, 6
3	Two-lab period mini-project: Project assignment included a simple hydraulic arm to be built from scratch using simple provided materials. The objectives were addressed and were evaluated by completion of project with neat and continuous operation while moving upward and moving 3-inches while rotating 90 degrees in the horizontal direction. Students were divided into groups of 3 students.	1, 2, 3, 4
4	Threaded discussions: Introduced a different question, an idea, a link each time and asked the students to analyze a problem and suggest a solution. Students were then required to review each other's solutions, providing at least one comment per solution. Identifying a problem and a solution contributed to 50% of the graded assignment and commenting on others' work 50% (Level of complexity was considerably increased with time).	2, 3, 4, 5, 6, 8
5	Laboratory experiments: This course includes 9 predetermined labs. Each one has different objectives and outcomes. Overall, the labs provide hands-on experience to 90% of the material discussed during lectures. Groups were randomly selected and members were swapped from lab to lab to make sure new teams are formed in each respective lab so that students get introduced to new teams and a variety of work techniques.	1, 2, 3, 4, 5, 6, 7, 8, 9

II. RESEARCH QUESTIONS

The inspiration for this work is the transformation of this course from a traditional lecture/lab format to one of an interactive nature. The transformation moves the course from an instructor-centered delivery to one that is student-centered. Student-centered environments have been known to increase communication skills, ability to work with others in a team, practice logical thinking skills, while being innovative and creative [2]. Evidence is also available that shows this kind of learning environment encourages quantitative reasoning and complex problem solving skills as they are routinely practiced in the work involved in this classroom pedagogy [3]. Other researchers and academics believe that not all learning outcomes can be addressed by this methodology, delivering less information than more traditional methods, possibly offering alternatives to the traditional lecture [4]. Proponents of the interactive classroom argue that improvement of the GPA is not the objective of this pedagogy, but rather providing information and methodology for students to deal with real life or authentic situations in the workplace [5] , [6]. Based upon these arguments the questions to be answered in this work include:

- *How does the overall performance of the students change when taking the course in a format or style that is different than traditional learning?*
- *Based on traditional learning results (for this course) (lecture + predetermined labs), how does the students' performance for the main campus differ from those at remote locations?*
    - *How do the comparisons change when hands-on exercises are applied for one location?*
- *Is there a relationship between the students' demographics and their performance?*

III. METHODOLOGY

The five listed approaches in Table 1 were applied and analyzed for one of the campuses. This campus is designated as "Site 1 hands-on". The class was taught Monday and Wednesday from 9:00 – 9:50 am and the lab was directly after lecture from 10:00 – 10:50 am. The results were collected for the same course at same site when traditional learning was followed using a lecture, take home assignments, quizzes, exams and the predetermined labs. This will be designated as "Site 1 – Traditional". All remote sites were aggregated together and named "All Remote Sites – Traditional", whereas main campus is designated as "Main Campus – Traditional". Note that all results and grades for all locations were based on traditional learning. Only "Site 1 hands-on" followed the 5-approaches listed in Table 1.

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The number of students along with demographics information are summarized in Table 2.

Table 2. Number of Students and Demographic Information for Various Sites Considered

Site Description	# students	Gender		Ethnicity					Age Range (years)
		Male	Female	White	Black	Hispanic / Latino	International	Others	
Site 1 hands-on	14	14	-	13	-	1	-	-	19-21
Site 1-Traditional	15	15	-	14	-	1	-	-	19-23
All Remote Sites - Traditional	98	92	6	92	4	1	-	1	19-43
Main Campus - Traditional	81	74	7	69	2	2	5	3	19-33

To answer the first question raised in the research questions section, two approaches were utilized. The first one included a survey filled by the students after each exercise and laboratory assignment. The survey was kept anonymous for students privacy purposes. The second approach looked into the overall performance of the students by investigating their GPA at the end of the semester. The survey used in the first approach consisted of three questions: the first question was phrased slightly different for each approach listed in Table 1, but it mainly targeted the percentage of correct answers obtained. Question 1 used for each of the five listed approaches in Table 1 are summarized Table 3. The second and third questions checked the interest of the students in the followed approach and whether they felt lost and needed guidance.

Table 3. Question 1 for Each of the 5 Approaches

Approach	Question 1 in the Survey
1	How many questions did your group answer correctly?
2	After comparing your answers with other groups' answers and based on comments from your instructor, how many questions did you answer correctly?
3	Was your project fully functional; if not please identify which section you couldn't achieve: Moving back and forth, lifting, rotating, or continuous operation?
4	How many students got the correct answers (identified a valid problem and proposed and reliable solution)? (to be answered by the instructor after reviewing all threads and participations)
5	How many students got the correct answers (within ±5% of the instructor's reference answers)? (to be answered by the instructor after reviewing the reports)

Questions 2 and 3 in the survey were:

2. **Were you interested in the class learning style followed today?**
3. **If the answer to (b) is yes, did you feel lost and needed more guidance? (Indicate the % lost?)**

The above three questions were used to investigate the first raised question in the "Research Questions" section. Approaches 1, 2 and 4 were repeated to achieve some consistency in the results. Approach 3 was more like a mini-project and was done once. Approach 5 included nine lab results, and was a little different than the other four Approaches.

The average, maximum, and minimum course grades were compared for main campus against all nine remote locations as an aggregated group when following only traditional learning to investigate any obvious differences in the performance of main campus against remote students. The remote aggregated approach would equate the number of students considered between the main campus and the remote locations and would dilute the effect of any outliner students at remote locations who might be too old and have too many years of experience. For qualitative comparisons only, the results for the site that applied the 5 approaches (hands on activities) presented in Table 1 would be presented along with the comparison to check for any big differences. During the surveys, demographics were collected including race, gender, and age-range. The same information for other locations was gathered through the campuses' administration database to check the diversity of students, the dominant race and gender, and if any relation exists that demonstrates the impact of students' demographics on their performance.

IV. RESULTS

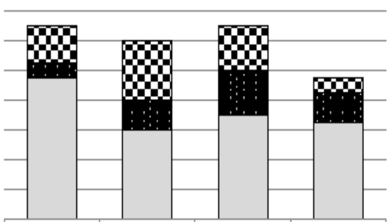
When referring to lecture + predetermined labs in this paper the terminology "Traditional Learning" is used.

For results related to the outcomes for the course that include hands-on exercises, the term "Interactive Learning" is used.

The survey responses for each of the four approaches (1, 2, 4, and 5) were tracked and recorded while collecting data for the three questions asked in each survey. The responses collected included multiple responses for the same approach including approaches 1, 2, 4, and 5.

The summary of the survey results are presented in Fig.s 1, 2, 3, and 4, respectively. Analysis of Approach 3 will be presented in a different paper as it was focusing on different set of skills including restricted time small project, team work, and project management skills. Another reason for not including Approach 3 in this paper is that it was done for one time only whereas the other four approaches were repeated for multiple times. The approaches are described in Table 1 presented earlier in this paper.

Based on the results presented in Fig. 1 through 4, it was observed that the level of students' interest in the different approaches ranged between 67-80%, as will be displayed in the discussion section in table form (Table 6). However, Fig. 1 shows the student responses in the four trials studied for Approach 1.

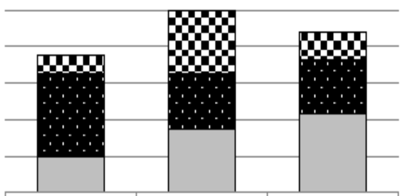


	Trial 1	Trial 2	Trial 3	Trial 4
Not interested	25%	40%	30%	10%
Interesed but felt lost	10%	20%	30%	20%
Correct answers	95%	60%	70%	65%

Fig. 1. Survey Results for Approach 1

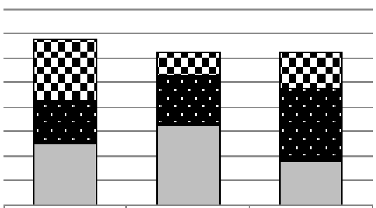
Fig. 1 shows the survey results for Approach 1. Trial 1 was straight forward and the students understood the material and assessment requirements, this was also true for the second class trial during the semester. Therefore, a high percentage of students achieved correct score. Reviewing the other trials, the number of correct answers is between 60-70%. Trial 4 exercise included the addition of a video related to the material and was presented to students prior to beginning the explanation of the approach (Approach 1).

Fig. 2 compares the survey results for Approach 2 which included the testing materials and development of a constrained project per directions provided to the students. Overall when comparing the approaches, this is the approach that garnered the lowest scores on the work completed.



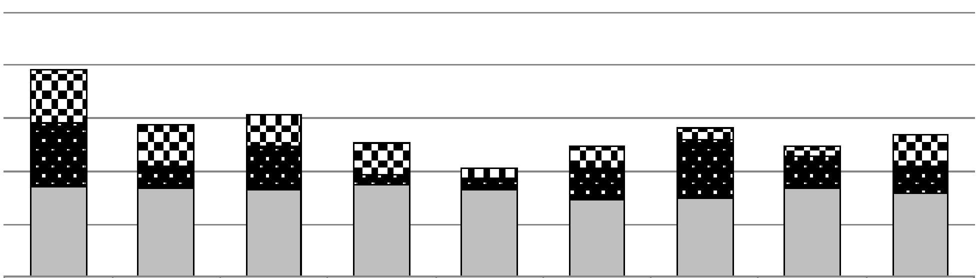
	Trial 1	Trial 2	Trial 3
Not interested	10%	35%	15%
Interested but lost	45%	30%	30%
Correct answers	20%	35%	43%

Fig. 2. Survey results for Approach 2



	Trial 1	Trial 2	Trial 3
Not interested	50%	20%	30%
Interested but lost	35%	40%	60%
Correct answers	50%	65%	35%

Fig. 3. Survey results for Approach 4



	Lab 1	Lab 2	Lab3	Lab 4	Lab 5	Lab 6	Lab 7	Lab 8	Lab 9
Not interested	50%	40%	30%	30%	10%	20%	10%	10%	30%
Interested but lost	60%	20%	40%	10%	10%	30%	55%	30%	25%
Correct answers	86%	84%	83%	87%	83%	74%	75%	84%	80%

Fig. 4. Survey results for Approach 5

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The highest average of correct answers were seen in the labs used for Approach 5 followed by these Approaches 1, 4, and then 2. Observations and actions were tracked for Approach 1, when lecture material was distributed during lecture time, and for Approach 5 (predetermined labs). These observations and comments are summarized in Table 4 and Table 5, respectively. Actions and observations were not tracked for other approaches, because either it was not applicable, students provided no feedback, or because the instructor was not able to record notes while executing the exercises.

Table 4. Observations and Actions Taken During the Execution of Approach 1

Trial	Observations / Actions Taken
Trial 1	Probably need to provide handouts to all students and not one student per group.
Trial 2	Distributed handouts at beginning of lectures.
Trial 3	Worked lab related to topic before lecturing.
Trial 4	Introduced a video from industry and then distributed the material with equations and explanation.

Table 5. Observations and Actions Taken During the Execution of Approach 5

Lab #	Observations / Action Taken
Lab 1	More information to be covered ahead of time; Lab assignments to be posted one week before lab. time.
Lab3	Students are not preparing for lab ahead of time; Lab objectives shall be covered during lecture time within the lecture material.
Lab 4	Seems that lecturing same topic in the same week helps; Grades are higher; Less people lost; Percentage of people not interested is still almost the same.
Lab 5	Distributed handouts ahead of time; lectured same topic same day.
Lab 7	Came back from Spring break; Lectured new topic same day; Handouts were posted online and were distributed during lab time.
Lab 8	Topic covered in lecture one class before the lab and during the same day as well.

Fig. 5 illustrates a comparison of the students' performance located at "Site 1" campus taking the course with traditional learning environment and with interactive learning environment in Spring 2016 and Spring 2017, respectively. The number of students in both cases were low as shown in Table 1 and, thus, making the results sensitive to outlier effects. For example, one of the students in the hands-on semester was careless throughout the whole course and did not interact in any activity, assignments, or even exams and, thus, got a score that was below 60%. That was observed as the most significant difference between traditional and hands-on results and it affected most of the hands-on results.

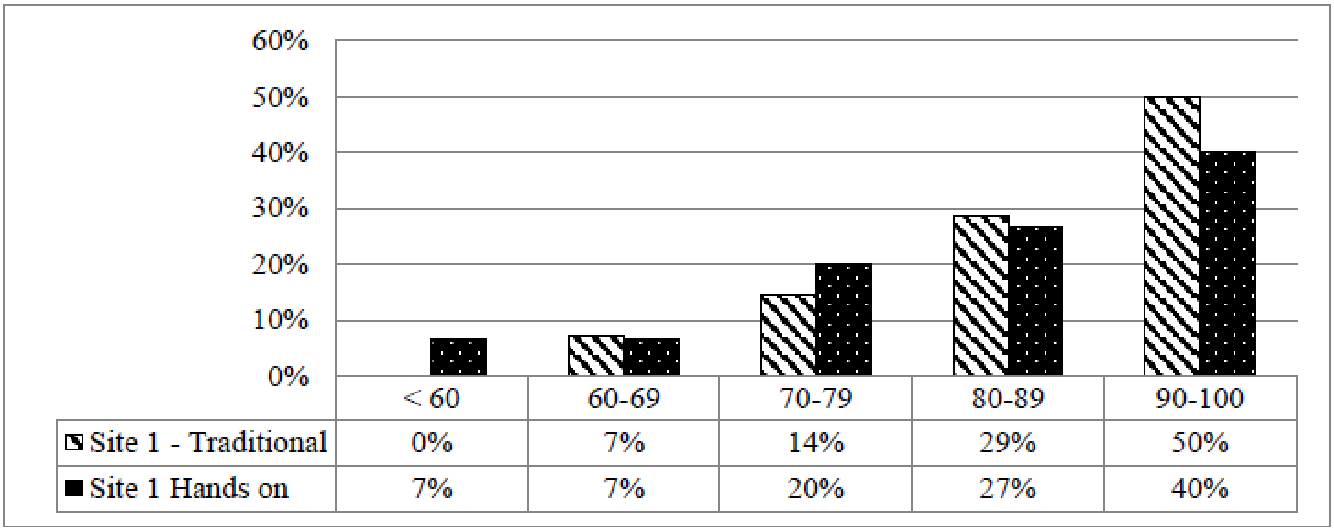

Fig. 5. Grades Distribution Comparison for Site 1 Traditional vs Interactive Learning Classes

To investigate differences between main campus and other remote sites, Fig. 6 shows a comparison for the maximum, average, and minimum grades under traditional learning styles between the main campus and the aggregate of remote sites. The results for "Site 1 hands-on" is also shown for further analysis. Fig. 7 shows the grades distribution for the given course at the 3 different sites.

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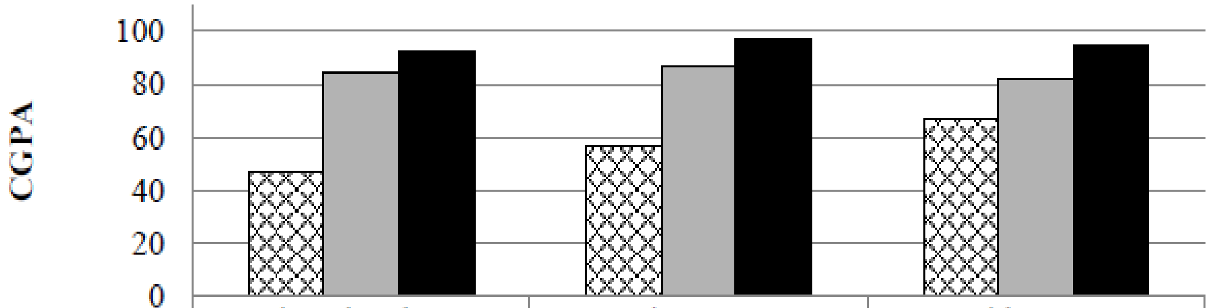
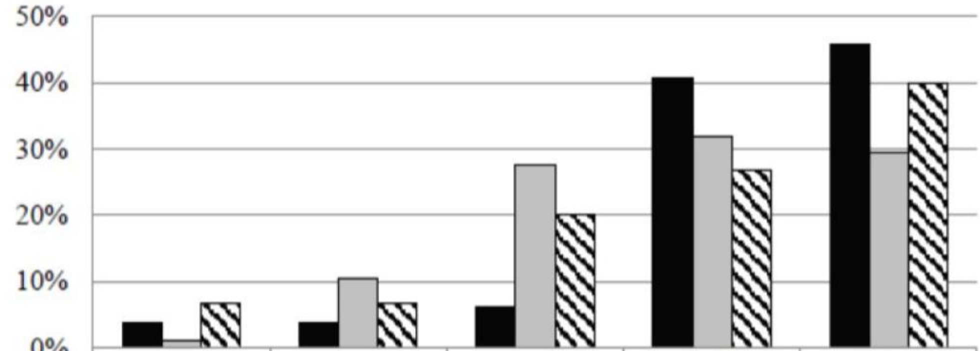


	Site 1 hands on	Main Campus	Statewide-Aggregate
Minimum	47	57	67
Average	84	87	82
Max	92	97	95

Fig. 6. Minimum, Average, and Maximum Grades for Various Sites.



	<60	60-69	70-79	80-89	90-100
Main Campus	4%	4%	6%	41%	46%
Statewide-Aggregate	1%	10%	27%	32%	29%
Site 1 hands on	7%	7%	20%	27%	40%

Fig. 7. Percentage of Students vs Grade Distribution

Respondents self-reported demographics displayed in Table 2 provides evidence that the majority of students at either the main or remote campuses are white males. Higher percentages of white males are evident at the remote campuses as compared to main campus. Remote locations do not host any international students and are less gender diversified compared to the main campus.

V. DISCUSSION

Survey results presented in Fig.s 1 through 4 are summarized in Table 6. The students' interest rates ranged between 67-80% for the four approaches (1, 2, 4, and 5) although the students did not get a high level of correct answers. For example, 80% of the students indicated that they enjoyed the group work testing in Approach 2 although it had the highest number of incorrect answers as compared to all of the approaches used in the class. This approach also was time restricted to 20 minutes as the testing was completed as a part of a lecture. Another reason for higher level of incorrect answers in this approach was some experimental error during measurements, and also had more calculations and unit conversion errors.

Student Response: Comparing a rate of 67-80% interest to 54-65% as reported in other work [7], this indicates that the students had similar interests in the material while attaining a similar performance to traditional learning techniques as provided and discussed in Fig. 5.

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Table 6. Average Percentage Student Responses

Approach	n=trials	Interested	Lost	Wrong Answers
1	4	74%	20%	27%
2	3	80%	35%	67%
4	3	67%	45%	50%
5	9	74%	31%	18%

Numerical Comparison: The number of students for all remote sites numbered 98 as compared to the 81 students studied on the main campus. There were 15 students in the group entitled "Site 1 hands-on" making the results dependent and sensitive to each individual result. Considering the comparison of Fig. 6 - mean, minimum, maximum values' differences between main campus and remote-aggregate the average for main campus appears to be slightly higher with nearly the same maximum value. The minimum in remote sites is higher than that for main campus.

The remote site that followed interactive learning had a centered average situating it between the averages of the main campus and remote-aggregate categories, with a lower maximum and minimum. Fig. 7 clarifies the differences between main and remote sites with 87% of students on main campus above 80 as compared to 61% for remote sites. Main campus has more students scoring in the grade classifications over 70 as compared to the remote aggregated group and the remote site with hands-on exercises. Comparing hands-on site results to overall remote results, clear comparisons were not available: the hands-on group had higher values for scores 90 and above and were lower than remote sites aggregated that followed traditional learning, for all other scoring ranges. However, the total number of students scoring 70 and above was almost 87-88 for either group. This was reflected in Fig. 7.

Table 7 provides a summary of demographic data, presented earlier in Table 2, providing evidence that the main campus student population responding to this survey are more diverse than remote campus'. White male students are in the majority at the remote locations, confirming other studies previously done on these populations [8]. Students responding from the main campus in this study consist of 6% international students; students of this category do not attend the remote locations. The Hispanic/Latino population is most heavily represented at the remote locations and there are more female students on the main campus. This study concurs with previous studies that the age range of students at the remote locations are far more dispersed than at the main campus [8].

In this study, it was determined that the students social and family status (married vs. non-married; having children), the nature of full time jobs, and the distance between the job location and university appeared to dominate the students' performance and not any of the variables presented in the demographic tables in Table 2 or Table 7. This dependency relationship between race and performance was shown not to exist by previous studies for the same university in the program of engineering technology [8], this may be due to the students responding to the survey.

Table 7. Demographic Data Analysis for Main Campus Versus Aggregated Remote Locations

Percentage	Main Campus (population=81)	Remote Locations Aggregated (population=98)
White	85%	94%
Male	91%	94%
Female	9%	6%
Largest Minority	Other	Hispanic/Latino

VI. CONCLUSIONS

Based on students' responses, it seems that the majority of students felt lost when prompted to identify a random problem and were asked to comment on one another's work (Approach 4 – Threaded Discussions) and when asked to apply the material learned in class directly using measuring tools and calculations (Approach 2). Approach 1 survey answers showed that students felt least lost and had the second highest correct answers following the predetermined labs (Approach 5). This would give an indication that the method of distributing lecture notes with equations and explanations included (Approach 1) was very useful in retaining the students' interest while directing them through the curriculum material and helping them understand the material. However, this should not undermine the impact of other approaches investigated. For example, Approach 2 does not indicate that the students did not understand the material, but rather there have to be some modifications done to achieve better results such as providing them with unit conversions tables, advising each member of the group to do the calculations to avoid or minimize any calculation errors, allowing them with more time, etc.

Comparison and analysis of the results for Approach 1 (Fig. 1 versus Table 4) revealed that the time of when lecture notes are distributed or whether the whole group or an individual has the notes, while the whole group discussing together, do not affect the results or retain more of the students' interest. It was Trial 4 when the students' interests scored high 90%. Thus, visual explanation of the problem before moving into details such as equations and explanations is of great interest for the students. Main campus students presented higher performance than students at remote sites following traditional or interactive learning class styles.

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Majority of students in remote locations tend to have a gap between their high school and university studies and most of them have more social and financial responsibilities than those on main campus whom the majority of them matriculate directly to university after finishing high school. The majority of remote locations students have full time jobs within 10-30 miles of the university, while the majority of main campus students have full or part time positions within the university that can help improve their academic background. These conclusions do not seem to be impacted by the race or ethnicity of the students in either the main campus or other remote site locations.

RECOMMENDATIONS AND FUTURE WORK

The authors are interested in repeating Approach 1 and in reapplying the comments and actions noted in Table 5 taken for Approach 5, comparing the results of both studies. Approach 1 is very well known among instructors who apply active learning techniques in their class leading to the question of, "How would the distribution of responses look like for a larger and a more diverse group of students?" The effect of visual presentations describing the class topic ahead of time is of great interest to the authors and they are looking forward to focus on this principle in the same course and in different courses, fields, and disciplines. Any readers who are interested in applying any of the approaches and interested in tracking the performance of their students are encouraged to contact the authors of this paper for result comparisons and potential research collaboration.

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Authors' Bibliography

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Anne Lucietto: Dr. Lucietto is an experienced engineer with years of experience in a variety of positions in different industries. She began as a mechanical engineer, working in progressively responsible positions requiring in-depth knowledge in mechanical, electrical, civil/construction, chemical and environmental engineering. She has spent significant time in the energy generation, chemical process, nuclear plant construction, operation, and material fabrication roles. Much of her career focused on facilities, maintenance, reliability, and various aspects of manufacturing management. She moved into teaching full time to help students successfully transition into careers in a variety of industries and to aide in their development into and through graduate school. Her research is focused on sustainable energy, and engineering education, with the intention of fully understanding engineering technology students.