

THE EFFECTS OF INCREASED VOCATIONAL HANDS-ON INSTRUCTION IN AN
ACADEMIC SCIENCE/TECHNOLOGY CLASSROOM

by

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DEDICATION

This project is for my mother and stepfather who helped send me on an educational journey to the United States in 1995. I can finally say I have completed that journey's goal thanks to their support, albeit a bit later than first envisioned. I want to also acknowledge the support given by Pathfinder administration, as well as the science department and vocational instructors that helped with this research project. Lastly, thanks to the many upper-classmen students who assisted with the integration projects. Those students were Maddie Dexter, Joseph Lomba, Triston Joyce, Gavin Racicot, Jon Willey, Tom Johnson and Ben Lamica. Their peer support cannot be understated and is a testament to those students in showing how to lead by example.

TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND	1
2. CONCEPTUAL FRAMEWORK.....	4
3. METHODOLOGY	8
4. DATA AND ANALYSIS	17
5. INTERPRETATION AND CONCLUSION	36
6. VALUE	38
REFERENCES	40
APPENDICES	43
APPENDIX A: HVAC Heat Transfer Activity	44
APPENDIX B: Electromagnetic Generator Activity.....	47
APPENDIX C: Hydraulic Brake Activity Worksheet	51
APPENDIX D: Example of Student Work.....	55
APPENDIX E: Student Journal	58
APPENDIX F: Student Survey Questions.....	60
APPENDIX G: Student Interview Questions Form.....	62
APPENDIX H: Sample of MCAS Multiple Choice Questions	65
APPENDIX I: Student Interview Questions.....	73
APPENDIX J: Institutional Review Board Statement.....	75

LIST OF TABLES

1. Data Triangulation Matrix	10
2. Demographics of Groups	11

LIST OF FIGURES

1. Pre- and Post-thermal Systems Assessment Scores.....	18
2. Survey Question on choice of Instruction for Thermal Systems	19
3. Pre- and Post-electrical Systems Assessment Scores	20
4. Electrical Systems Survey Question Responses	21
5. Survey Question on Choice of Instruction for Electrical Systems Comparison Group.	22
6. Pre- and Post-fluid Systems Assessment Scores	23
7. Comparison Group Fluid Systems Survey Question Responses	24
8. Treatment Group Fluid Systems Survey Question Responses	25
9. Survey Question on Choice of Instruction for Fluid Systems for Comparison Class ...	26
10. Survey Question on Choice of Instruction for Fluid Systems for Treatment Class.....	27
11. Pre- and Post-communication Assessment scores for Comparison Class	28
12. Comparison Group Communication Technology Survey Question Responses	29
13. Treatment Group Communication Technology Survey Question Responses	30
14. Survey Question on Choice of Instruction for Communication Technology for Comparison Class	31
15. Survey Question on Choice of Instruction for Communication Technology for Treatment Class	31
16. Treatment Group Survey Response for Effectiveness of Hands-on Activity	32
17. Pre- and Post-assessment Scores and Normalized Gain	33
18. Mean Pre- and Post-assessment Scores	34

ABSTRACT

This project was conducted at Pathfinder Regional Vocational Technical High School (PRVTHS), where students receive a regular high school academic education, as well as vocational instruction in a designated technical program area. This vocational instruction is largely hands-on instruction. This project examined whether increasing that style of learning into a science/engineering classroom would increase student learning as well as student engagement in the subject of technology/engineering. Problem based hands-on teaching has been shown to provide a sound foundation for instruction and student engagement. Hands-on experimental activities have been at the core of science classrooms and administration has lobbied teachers to expand hands-on integration between academic and vocational departments. This study covered four technology/engineering frameworks, (thermal systems, electrical systems, fluid systems and communication technology), and worked with four vocational areas to help cover that content, (Heating, Ventilation and Air Conditioning, Electrical, Automotive Technology and Electronics). The treatment groups received hands-on instruction in a vocational area, and the comparison groups received traditional classroom learning.

Quantitative data showed that both the treatment and comparison groups increased post-assessment scores; however the treatment group did not significantly outperform the comparison group. That said, qualitative data gathered from student journals, surveys and interviews delivered an overwhelming response that hands-on instruction heightens student engagement and is the preferred method that students wish to be taught. It is essential to increase this style of learning between the vocational and academic departments at PRVTHS to help with student enrollment, as well as increasing student engagement to improve student performance.

INTRODUCTION

During the time of this project, I taught chemistry, earth science, physics and technology/engineering at Pathfinder Regional Vocational Technical High School (PRVTHS) in Palmer, MA. I had 122 students in total across these subjects, but the primary class I taught was the ninth grade technology/engineering class with 72 students. I taught from a syllabus that was aligned with the Massachusetts State Frameworks for high school technology/engineering and all of my students took the Massachusetts Comprehensive Assessment System (MCAS) test at the end of the year. This was mandatory for all PRVTHS students and they needed to obtain a proficient or better score in order to graduate from high school with a diploma. Historically, the majority of teaching in technology/engineering has been predominantly textbook-based with few hands-on activities, which has led to lethargy and, in turn, poor performance. While testing scores at PRVTHS are currently above the state average, there is room for improvement.

Teaching is split evenly between vocational instruction and academic education at PRVTHS. Compared to the academic classroom, instruction in the vocational school/classroom was overwhelmingly taught via hands-on instruction and activities with some classroom related theory as well. The academic classrooms followed a more traditional approach that might be seen in the majority of high schools: through instruction via textbooks aligned to a curriculum. The difference in teaching methods between academic and vocational classrooms at PRVTHS led me to wonder if teaching academics via similar methods to those used in vocational classrooms, would help engage students more and thus increase student performance.

Hands-on learning can certainly be applied to the various disciplines within science such as physics, chemistry and biology, and the ninth grade class on technology/engineering would seem to work hand in glove with this kind of learning approach. Hands-on learning is already becoming increasingly popular within career technology institutions (Anderson & Swafford, 2011; Cannell & Zavaleta, 2010). Hands-on learning is also a technique seen to be more valid with schools that have adopted the Common Core, (Kaiser & Kaiser, 2012), and Pathfinder was in the process of adapting this teaching strategy.

Standardized tests are mandatory for all students and they must achieve a passing score in order to be eligible to graduate with a high school diploma from PRVTHS. Student success in the classroom, therefore, transcends simply gaining student interest in the subject, to having them prepared as best as possible to pass these tests. This can lull an educator into “teaching to the test” to ensure that student performance is sufficient to meet a proficient level score. At PRVTHS, there is a curriculum generated to align and cover all the state frameworks and an appropriate textbook is selected and used in order to cover those frameworks. This traditional approach to teaching usually has students working independently rather than in groups, except for the occasional lab-based project.

Although the majority of teaching had this independent approach, it seemed counterproductive for a subject such as technology/engineering because the very cornerstone of this subject is the engineering design process, which requires teamwork to analyze and solve problems. In fact, group activities are more likely to mirror the skills used in a typical everyday workforce and so it seemed prudent to teach more of those problem solving skills to students, especially those attending a high school where they

will learn a trade. Furthermore, integration between vocational and academic departments is something that the administration at PRVTHS had adopted, and they had worked with a representative of the Massachusetts Department of Education along with a team of in-house vocational and academic teachers to further develop this.

The year prior to the project, PRVTHS was dropped by the Massachusetts Department of Education from a level 2 school to a level 3 school due to poor MCAS scores primarily in the area of mathematics. While science scores were above the state average, there was a level of uneasiness throughout the school, especially within the administration, and strategies were put in place to increase student performance across the corresponding subject areas. A greater inclusion of mathematics into the vocational programs was planned, and this treatment explored whether a greater inclusion of hands-on vocational activities into the academic engineering/technology classes would help students comprehend subject matter better.

The primary question was, “How do increased hands-on integrated activities between vocational and academic areas improve student understanding and help encourage higher-order thinking?” Secondary questions explored whether students’ attitudes towards technology/engineering improved with more hands-on activities: “How do student attitudes towards technology/engineering change with more hands-on activities?”, and “How does student understanding about engineering change after hands-on activities have been implemented in the classroom?”

CONCEPTUAL FRAMEWORK

Students who choose to attend a vocational technical high school base their decisions primarily on gaining the tools of a workforce trade upon completion of their high school education. In typical vocational programs, academics are firmly integrated within the educational experience and certain academic requirements, such as a passing score on state standardized tests, must be met in order for students to graduate with a diploma. Upon leaving a vocational technical high school, students are in a favorable position of having the choice of furthering their education at the collegiate level or entering the workforce in their corresponding trade. In some cases, academically eligible junior students can be placed in a local area business during their shop week for school.

Applying problem-based learning through a hands-on approach has a sound theoretical approach and provides a foundation for successful instruction and learning (Marra, Jonassen, Palmer & Luft, 2014). By applying problem-based approaches to instruction, learning is driven through solving an actual problem, which is at the core of the engineering design process. With this method, students are active members of applying subject knowledge and developing new ideas and strategies to solve an authentic problem. Students are compelled to explore sources other than the textbook for answers, and brainstorm ideas that will provide the best solution possible to solve the problem (Marra et al., 2014). The learning environment, as defined by Marra and colleagues (2014), has problem-based learning with the following central characteristics: 1) Problem-focused, 2) Student-centered, 3) Self-directed, 4) Self-reflective, and 5) Facilitative. The focus is to encourage everyday learning both during school and after the students leave. An important approach with this method is that students are presented

with a problem before any learning has occurred. This counters any traditional approach of education and encourages individual research. The process cumulates in a group setting taking the various independent thoughts and ideas and molding them into a common goal to solve the problem that has been presented.

Throughout all science curricula at the high school level, what always appears to be central in any scientific discipline when change to curricula is suggested, is the extension and application of hands-on experimental activities (Korwin & Jones, 1990; Wen-jin, Chia-ju & Shi-an, 2012). In addition, students are more engaged when there are laboratory activities taking place rather than bookwork at a desk (Korwin & Jones, 1990; Anderson & Swafford, 2011; Lasky & Yoon, 2011; Murphy, Varley & Veale, 2012). Therefore, it would be sensible to ask whether an increase in these hands-on activities is more beneficial to students than a traditional textbook-centered approach to teaching.

Work by Korwin and Jones (2011) and Wen-jin and colleagues (2012) examined whether hands-on technology-based activities enhanced learning by reinforcing cognitive knowledge and retention. They took a philosophical look at the history of hands-on activities being applied to education and then focused on more recent studies that identify physical and mental performance when both cognitive and psychomotor learning activities are applied. Their objective was to determine if any measurable difference in student knowledge could be seen once hands-on technology-based activities were given to supplement regular classroom instruction. Their methodology involved a broad demographic of four eighth-grade industrial art and math classes. Two groups were randomly created and two methods of instruction were given for a 40-minute lesson on geodesic domes. One group received information through reading and a hands-on

activity, whereas the other gathered information via reading and an illustrated lecture. A post-test was administered the following day, and then again two weeks later to measure retention. Statistical data showed that the group using the hands-on approach scored better than the other group in both of the post-tests. Wen-jin et al. (2012) concluded that the results of their research “have significant implications for general education and specifically technology education” (p. 32).

Traditional high schools can apply hands-on activities with laboratory exercises or classroom projects, but it really is only at a vocational technical school where one can fully apply real life integration with trades (Lucas, Spencer & Claxton, 2012).

Application of academic subject matter concepts when used in conjunction with a vocational trade has been shown to help students with subject matter retention (Lucas et al., 2012). In their 2012 paper, Lucas and colleagues provided an extensive in-depth look at the theoretical pedagogy of teaching vocational education. While their study focused solely on vocational instruction and not on academic teaching, there are some extremely useful tools and teaching methods that maximize the impact of teaching to students who receive both when they attend a vocational high school. One of the most useful areas of their study was a look at the preferences of a vocational learner when selecting the right teaching method. Lucas et al. (2012) state that a key part to this approach is that although learners will all have their particular preferences, it is how the teacher chooses to present the material that is more important than the individual’s preferences.

Fundamentally the theoretical working of this style of learning now has an important place in education given the extent and ease of information access via the Internet. Students have access to a world of knowledge on a device as simple as a

cellular phone, and technology is seen to be an important component of hands-on problem solving learning (Korwin & Jones, 1990; Lasky & Yoon, 2011; Branson & Thomson, 2013). As knowledge is nurtured and stimulated when questions or problems are presented, it is our interactions with the environment that will be constantly provide us with further questions and a desire to solve those problems (Marra et al., 2014). As the United States continues to move towards having a more robust workforce in science, technology, engineering and mathematics (STEM) fields, it is critical to apply more technology into learning and problem solving activities (Lasky & Yoon, 2011).

One area that may be useful to explore with the application of hands-on activities is that of the role of virtual simulations in the classroom. Student engagement is a big piece of the learning puzzle, and by using virtual technology the instructor is able to bring real-world activities and problems into the classroom (Branson & Thomson, 2013). Exposing students to a more mature and adult-based setting has been shown to increase confidence (Lucas et al. 2012; Branson & Thomson, 2013). Another benefit to virtual learning is that a lot of the technology is connected with companies with which students can already make a connection, like Google.

Branson and Thomson (2013) examined a school in Pennsylvania that was using virtual technology that the US Navy also used. This use of technology allowed the school to expose the students to real-world issues and problems when posed with the problem of having limited resources. Students worked in groups and collaborated with each other by applying their STEM knowledge to solve the problem of redesigning a virtual environment that included energy and power sources such as nuclear energy and green technology. Brainstorming was central to this as were the aspects of design and

safety. The school utilized Google Earth for this project, as well as the exact same software and technology that the US Navy uses in their simulations. Students kept journals to track their progress and to check for understanding by the teacher. At the end of the project the groups presented their solution to the school and were assessed on various criteria such as their collaborative efforts, quality of the content of their presentations and completion of the virtual nuclear power plant inspection. Branson and Thompson (2013) concluded that “bottom-line, hands on problem-based learning has increased student engagement and learning” (p. 21).

With the examples of successful hands-on activities and the teaching approach to vocational students that comes with that, then some good initial tools are already in place to address the problem of improving the cognitive learning of vocational students in high school science/technology classes. What appears to be the most important theme from the reading is to make the hands-on activities authentic problem-based activities that apply to real-world scenarios. It is also important to not make these hands-on activities seem like playtime to the students, and that longer term projects as opposed to shorter, smaller projects tend to result in greater student engagement (Robertson, 2008; Lucas et al., 2012).

METHODOLOGY

This project covered four months from January 2016 to April 2016 with my ninth grade technology/engineering science students. At PRVTHS, students split time equally between academics and vocational shop areas, which translates into approximately eight academic weeks for the students. I wanted to know if more hands-on integrated activities between vocational and academic areas improved student understanding and helped

encourage higher-order thinking (Table 1). The application of this treatment was intended to address two areas of concern: to help students better understand subject matter, to help them pass the end-of-year standardized test, and to help school administration better integrate vocational and academic areas via peer collaboration.

This treatment was administered to all my 2015-16 ninth grade technology/engineering science students. This subject is mandatory for all incoming freshmen at PRVTHS, and each student is required to take the MCAS test for this subject at the end of the school year. The scores of this test not only dictate whether students can graduate with a high school diploma, but also provide students with an opportunity to qualify for scholarship funds if their scores are deemed advanced, a score of 260 or above.

Table 1
Data Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
Primary Question: How do increased hands-on integrated activities between vocational and academic areas improve student understanding and help encourage higher-order thinking?	Pre- and post-framework assessment tests	Pre- and post-framework surveys	Teacher observations
Secondary Question: How do students' attitudes towards technology/engineering change with more hands-on activities?	Pre- and post-framework surveys	Student journals	Teacher observations and student interviews
Secondary Question: How has my students' understanding changed about engineering after hands-on activities have been implemented in the classroom?	Pre- and post-framework assessment tests	Teacher observations and student interviews	Student journals

I had four 60-minute technology/engineering science classes each day, with enrollments of 13, 17, 20 and 23. Many students were serviced with an Individual Education Plan (IEP) (Table 2). I implemented the treatment with two of these classes and left the other two with a traditional teaching approach as a comparison. Treatment classes were alternated for each hands-on integration project.

Table 2
Demographics of Groups

	Treatment	Comparison
Thermal Systems	34 students (20 male, 14 female, 50% on IEP)	39 students (24 male, 15 female, 47% on IEP)
Electrical Systems	38 students (21 male, 17 female, 50% on IEP)	35 students (19 male, 16 female, 49% on IEP)
Fluid Systems	43 students (27 male, 16 female, 56% on IEP)	30 students (18 male, 12 female, 45% on IEP)
Communication Technology	29 students (14 male, 15 female, 41% on IEP)	44 students (26 male, 18 female, 55% on IEP)

The subject content for the first integration project covered energy systems, in particular the way in which heat flows through a system. It centered on group brainstorming to solve problems, and paired well with hands-on vocational activities. For this project I worked with the Heating, Ventilation and Air Conditioning (HVAC) Department. Students were placed into two groups that worked separately applying heat to various materials and recording temperature change via heat transfer by either conduction, convection or radiation. The students spent two days in the shop area and worked with various conductors and insulators applying heat to both and describing the differences in how the heat energy flowed (Appendix A).

The second project further explored energy systems, this time looking at electrical systems. Once again, this provided an excellent opportunity to apply various hands-on vocational activities into my treatment classes. Students spent three days in the electrical shop examining the framework details pertaining to electrical systems. Students were exposed to course content while working with direct current, volt meters, ammeters, oscilloscopes, and were required to build both series and parallel circuits as well as a basic electromagnetic generator (Appendix B).

After the classes covered electrical systems, the topic shifted to fluid systems where hydraulic and pneumatic systems were covered. Students identified the similarities and differences between each fluid system, and also had to calculate the force multiplication associated with a hydraulic system. Automotive instructors received state framework language and copies of previous MCAS fluid systems questions well ahead of time to help them formulate some appropriate hands-on activities. Students spent two days in the shop during which the four classes were split into two groups with one working on pneumatics and the other hydraulics. This unit had a worksheet component, (Appendix C), with problems on force multiplication based on student measurements of the hydraulic components, (Appendix D).

Finally, students examined communication technology and focused on the difference between digital and analog data signals, paying close attention to how fiber optics work by using total internal reflection. Students were again in small groups with one group examining the difference between what digital and analog signals were, with emphasis on the binary system used for digital signals. The other group worked with fiber optic cable to see how it is able to send a digital signal and the benefits of more bandwidth with a digital signal.

When the treatment classes were in the corresponding shop areas, the comparison classes remained in the classroom and received course material via slides, video presentation, bookwork and answering chapter questions from the book. Data were consistently gathered by administering a pre-assessment for all four classes before any class had been exposed to the subject content. Then the same assessment was re-

administered after all the classes had worked on either a vocational hands-on project or traditional classroom bookwork.

Student journals, (Appendix E), and surveys (Appendix F) were completed by the treatment classes, while the comparison classes were asked to complete a survey only. Interviews were attempted in treatment classes. However, the return and success of the first interviews were discouragingly weak so I changed my interview approach to an online interview form where students were encouraged to answer certain pertinent questions as openly as possible (Appendix G).

Pre- and post-multiple choice assessments were developed for each framework and given to both treatment and comparison classes. Questions were selected from previous MCAS tests (Appendix H) so as to familiarize and prepare students with how test questions might be structured for their MCAS test in June 2016. Each assessment was 20 questions in length, and the same assessment was used in both the pre- and post-assessment for each framework. Assessments were scanned by the Apperson Datalink scanning machine, and software applied to produce the appropriate statistical data.

Data from these assessments were purely quantitative with resulting nonparametric frequency data summarized using boxplots. Differences between the two classes were assessed for statistical significance using the Mann-Whitney test with an alpha level of 0.05. A *t*-test was applied to compare all assessment scores between treatment classes and comparison classes to see if there was a statistical difference between the two class scores. Normalized gain was calculated using Hake's method

(1998) and applying the formula $G = \frac{\text{post score \%} - \text{prescore \%}}{100 - \text{prescore \%}}$

Hake (1999) determined that a G value of greater than 0.7 indicates high normalized gain, a medium gain is between 0.7 and 0.3, and scores less than 0.3 are considered low normalized gains.

Class observations and logistical difficulties were identified using a Teacher Journal. This journal was a daily account as to how each class went, citing areas of success or difficulty with my classes based on teacher observations, and entries were made for both treatment and comparison classes. In addition, all hands-on activities were observed by a school administrator.

A key intention was to target specific hands-on activities that the vocational shop teachers use to increase level of familiarity and integration between the vocational and academic departments at PRVTHS. Currently separate coordinators oversee the vocational departments and academic departments; however, the administration would like to see more integration and collaboration between the two, and the administration was incredibly supportive throughout the data collection phase. Administration at Pathfinder also requested regular consultation so they could monitor the instruction being given to all of the students and this provided valuable feedback data throughout the time the treatment was being administered.

Each of my students had their own Google account that came with a cloud storage feature, called Drive, that they used to upload and create documents, spreadsheets and slides. I was able to create the surveys, the journal format and interview questions using Google Forms, share them with the appropriate students in the corresponding classes, and receive students' responses via email.

The purpose of the journals was to get a look at the students' perspectives regarding what they learned in class, what they enjoyed the most, what they least enjoyed working on and also what concepts they found easy or difficult to comprehend. These student journals helped to answer both of the secondary focus questions:

- What area of the course have you been working on recently and what framework does that come under?
- What lessons or activities did you enjoy the most during this framework?
- What lessons or activities did you least enjoy during this framework?
- What concepts did you find easiest to learn?
- What concepts did you find hardest to learn?

Students worked on their journals during their Friday class after they had completed the post-assessment. If class time expired for some students before they could finish their journal entry, they were instructed to work on it as a home assignment during their shop week. Each PRVTHS student had access to their school Google account and could access their Drive anywhere they had Internet access, such as at home or during library time at school. Data were collected from student journals in the form of quotes that showed support or problems with the implementation strategy.

Students' surveys were used at the beginning and the end of a framework to establish student understanding with the course material and helped answer all focus questions. The surveys were administered via Google Forms using a Likert Scale and questions were presented using an ordinal scale of 1 to 5, covering these five options respectively: strongly disagree, disagree, neutral, agree, strongly agree. The format of

these surveys remained constant and the category answer options consistent with all surveys administered for all of the hands-on activities.

A smaller survey-like activity, called a Minute Paper (Angelo & Cross, 1993), was used during the electrical systems project. This activity assessed whether the treatment was working or not as the electrical systems project seemed to generate the most student frustration. Data from the Minute Paper was shared with the electrical instructor and it helped us adjust the activity to focus more on practical hands-on and less theory on electrical systems.

Select students were interviewed in order to answer both the secondary focus questions that examine attitude towards the subject content and a better understanding of course content. In total, eight interviews were conducted by selecting students based on their class grade ranging from failing grades up to 'A' students. The first two verbal interviews were with a small group of students, but they were reluctant to talk. I therefore decided again to administer interview questions using Google Forms, where open questions were presented and students were encouraged to write their responses down. Although this does not adhere to the traditional interview format, the goal was to collect data. This method provided more data than the first two traditional interviews and so was used throughout the rest of the data collection period.

I conducted two kinds of interviews, each with different question formats: unstructured and semi-structured. The unstructured interview was candid and free flowing, with the students determining the direction, and with minimal coaxing. My hope with the unstructured interview was that I would uncover a clearer honesty from my students as they were free to discuss and talk about topics that they wanted to talk about,

or were most interested in. This did not work out well, and responses were infrequent, brief and lacking valuable insight but consisted of an interview guide in the form of a list of key questions that I asked via a Google Form. This interview was therefore not verbal in nature, but did provide students an opportunity to voice their thoughts and ideas about the hands-on activity instruction that they received. The guide also allowed me to cover the same topic areas with all of my interviewees in the different classes.

The wording of this interview was adapted from Kvale (1996) (Appendix I). Data from these interviews were used in the form of student quotes listed in an appendix and referenced in the data analysis section. Interview data were also used to identify critical areas of concern throughout the treatment process. This was shared with vocational instructors so delivery of the treatment and further data collection instruments could be modified to help the effectiveness of the treatment and respond to students' frustrations.

Participation in these journals, surveys, assessments and interviews was voluntary and participation or non-participation did not affect a student's grade or class standing in any way. The research methodology for this project received an exemption by Montana State University's Institutional Review Board (Appendix J), and compliance for working with human subjects was maintained.

DATA AND ANALYSIS

Quantitative data were collected for each unit via pre- and post-assessments for both comparison and treatment classes. Surveys of the comparison and treatment classes and student journals and interviews of the treatment classes provided qualitative data. The first integration project was with the HVAC department, and comparison classes spent two days in the shop area examining heat transfer along with conducting and

insulating properties of materials. Due to three ‘A’ students being absent on the day of the post assessment, there was a slight drop in the median scores from pre- to post assessment for the treatment group, but the scores rose from 55% to 68% in the comparison group (Figure 1). As all tests were taken anonymously, it was impossible to prevent this problem from affecting the data. Normalized gains for this unit were low, with gains of 0.26 and -0.04 for the comparison and treatment groups respectively. The change in pre- and post-assessment scores was statistically significant for the comparison class with CI = 95% [53%, 63%] and $p = 0.065$. However, for the treatment class those scores were not statistically significant given the lower mean score for the post-assessment.

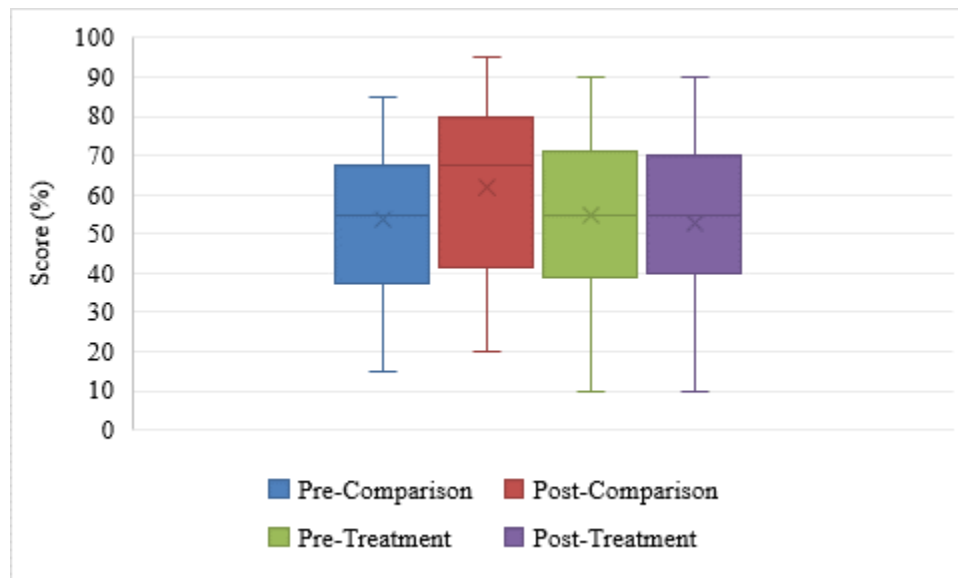


Figure 1. Pre- and post- thermal systems assessment scores, ($n=39$ for comparison, $n=34$ for treatment).

While the treatment post-assessment scores did not improve as much as the comparison classes' scores, the feedback from the surveys and student journals clearly showed that students preferred some sort of hands-on instruction. Surveys were

supposed to be separate for both comparison and treatment groups, but a logistical error was made and so responses from both groups came back in the same survey. A sample of the online survey questions (Appendix E) relating to thermal systems showed that the majority of the students favored a level of hands-on instruction over bookwork (Figure 2).

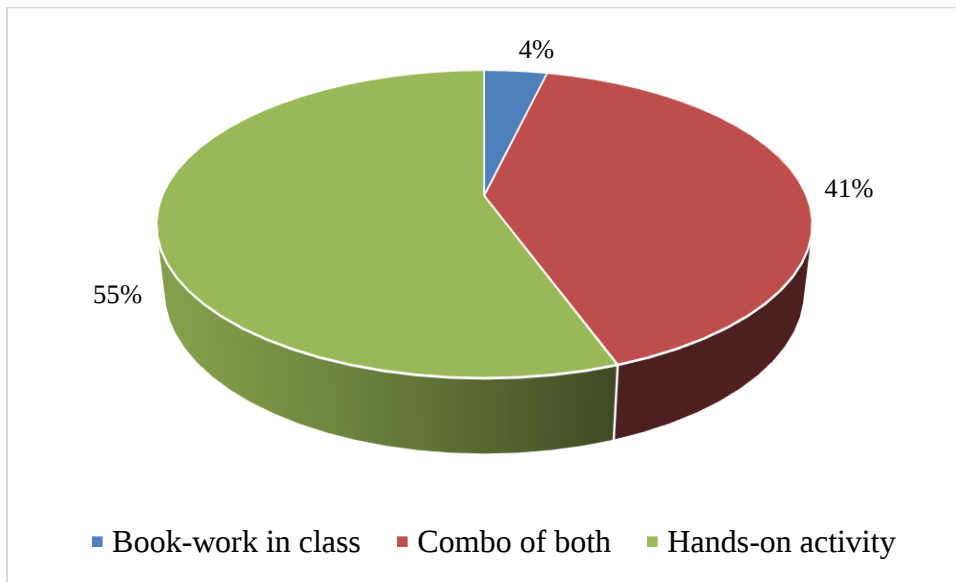


Figure 2. Survey question on choice of instruction for thermal systems, (N=54).

Student journal entries confirmed that the majority of students prefer a more hands-on approach. When asked what they enjoyed the most when learning about heat transfer, some responses were, “I enjoyed going down to HVAC and doing more hands-on stuff, its [sic] always nice to get out of the classroom and open up your mind to new things. I’d say it was a succesful [sic] week”, “The best part of the thermal systems was when we had claas [sic] in HVAC heating difrent [sic] things and seing [sic] how the heat transfers to diffrent [sic] parts of the object” and “I enjoyed going down to HVAC and experimenting with different components for heat transfer.”

Comparison classes for the thermal system integration project became treatment classes for the electrical systems integration project. This time the project ran longer in the electrical shop, spanning six class periods. All four classes were given the same pre- and post-assessment questions and median scores rose for both groups (Figure 3) with the comparison group showing a better improvement overall.

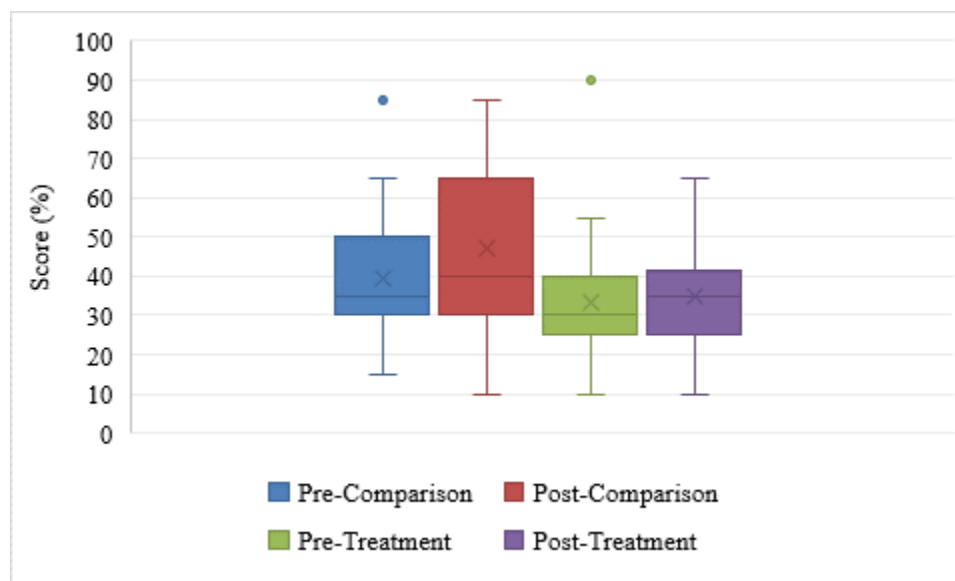


Figure 3. Pre- and post-electrical systems assessment scores, ($n=35$ for comparison, $n=38$ for treatment).

Both groups demonstrated low normalized gains with $G = 0.18$ for the comparison group and $G = 0.24$ for the treatment. A Mann-Whitney test was run and the null hypothesis for comparison group's assessment scores was rejected ($p = 0.04$). However, for the treatment group the null hypothesis was not rejected ($p = 0.08$). Therefore, only the comparison group's low normalized gain scores from pre- to post-assessment were statistically significant.

Figure 4 shows the treatment and comparison groups' survey responses for their confidence about the material after their corresponding activities. The comparison

group appeared more comfortable with the material, perhaps due to the familiar format of traditional teaching methods. Nonetheless, the feedback from the survey question about

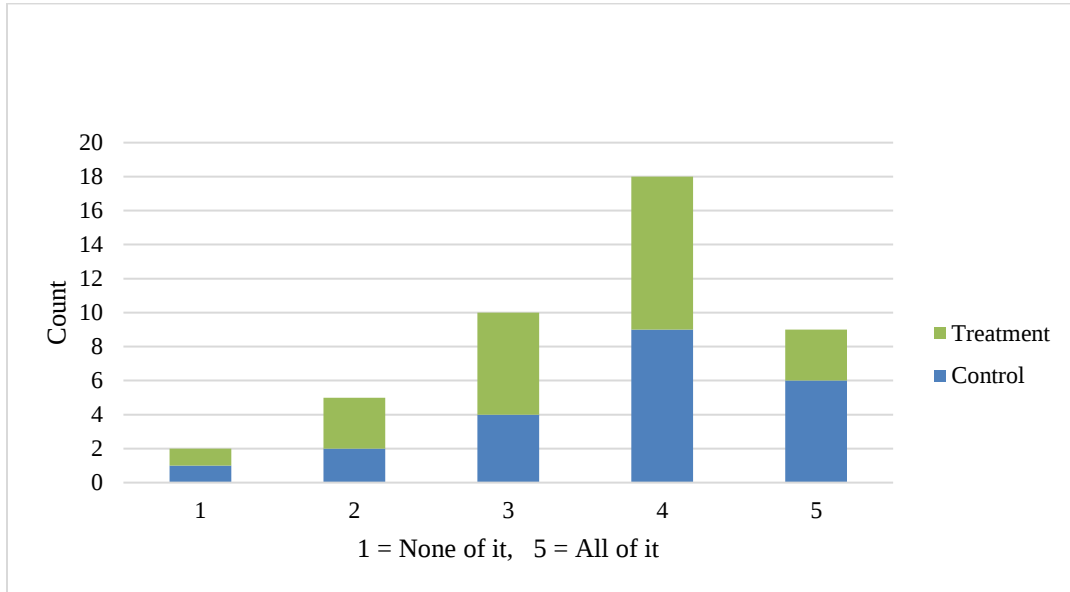


Figure 4. Student responses about how much they understood about the methods of electrical systems, (n=22 for treatment, n=22 for comparison).

what form of instruction they prefer (Figure 5) and the student interview responses overwhelmingly showed that students preferred hands-on instruction in some capacity.

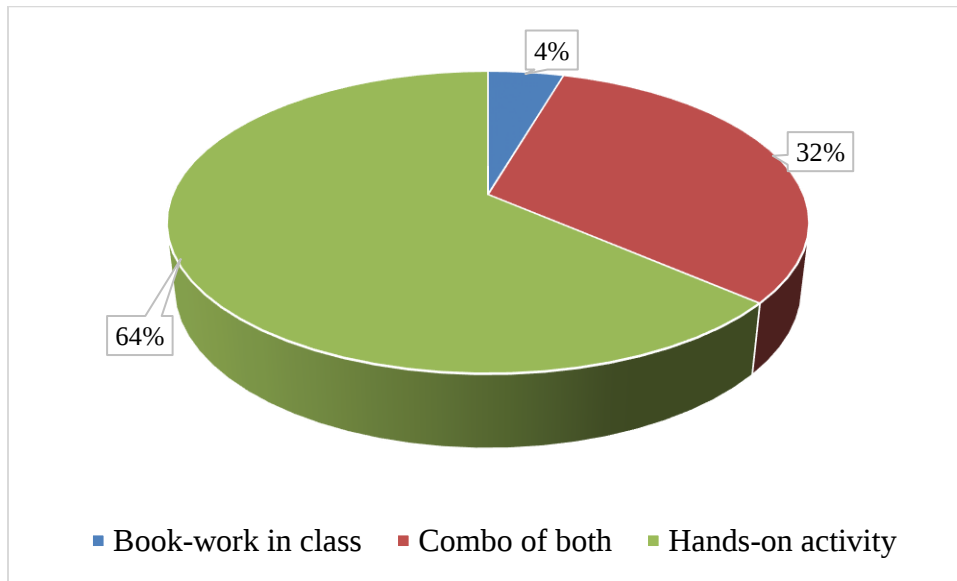


Figure 5. Survey question on choice of instruction for electrical systems comparison group, ($n=22$).

When students were interviewed and given the question “Should Pathfinder be doing more integrated teaching involving both the academic and vocational shops in subjects such as science? Why or why not?”, some responses were as follows:

- “Yes, I think there should be both academic and shop for classes like science because everyone learns differently, like for the people who are more book learners, the academic part is for them and for the others who are hands-on they can also do something they like and enjoy.”
- “Yes they should cause [sic] usually kids that come to pathfinder [sic] are good with visual hands-on project.”
- “Yes it creates a better understanding for the materials.”

Of the ten students chosen for interview in this integrated activity, eight provided answers like the ones mentioned, or were at least positive about the experience. The other two were uncomfortable with the hands-on activity and gave answers such as, “no because if we wanted to learn that much we should've picked the shop and not interfere with their

time” and “no because it would be easier for them to be separate from the class and not do their work as people can do pretty much what they want.”

To cover fluid system concepts such as hydraulics and pneumatics and the role of force multiplication, I worked with the automotive department. Comparison classes were in the academic classroom all week, and the treatment classes spent three days in the automotive department. This time, assessment score results differed from the trends seen with thermal and electrical systems with regards to improvement between pre- and post-assessment scores from comparison and treatment groups (Figure 6).

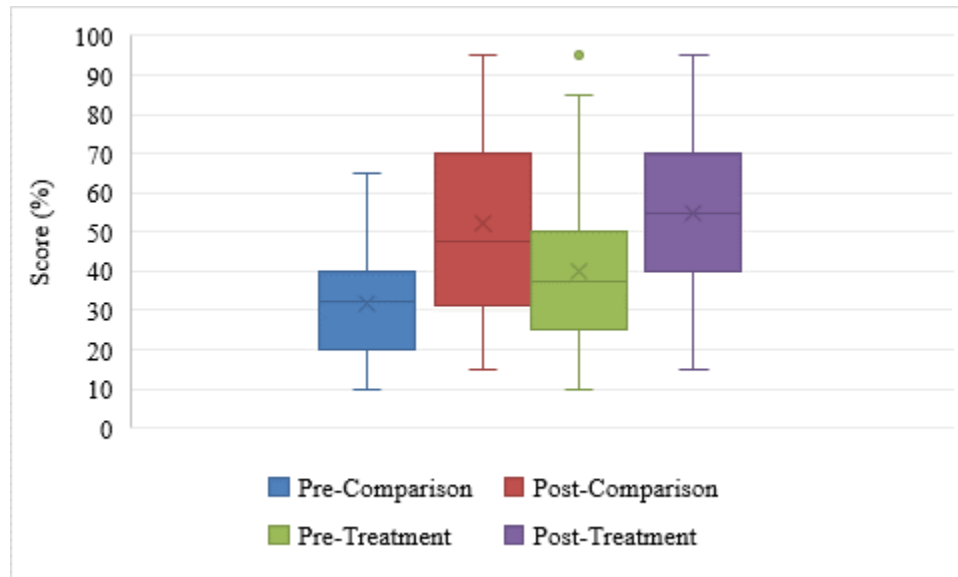


Figure 6. Pre- and post-fluid systems assessment scores, ($n=30$ for comparison, $n=43$ for treatment).

Both groups showed pre-assessment median scores were comparable and both groups' post-assessment scores also improved. Normalized gain values for both groups were similar but both had low gains with $G = 0.28$ for the comparison group, and $G = 0.25$ for the treatment group. Once again both groups' pre- and post-assessment scores were analyzed using the Mann-Whitney test. In both cases the null hypothesis was rejected

for both the comparison ($p = 0.003$), and the treatment group ($p = 0.0006$). The gains in the post-assessment scores were statistically significant.

Feedback from the surveys administered to the comparison class showed that students clearly came into this week knowing very little of the course material (Figure 7) but by the end of the week felt a lot more confident with the subject matter.

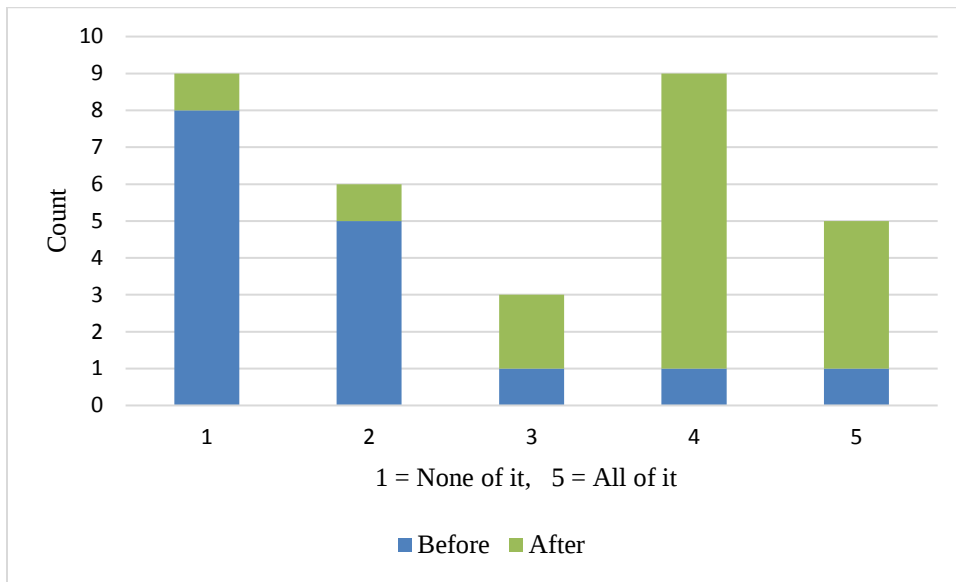


Figure 7. Comparison group responses about how much they understood about the methods of fluid systems before and after instruction, ($n=16$).

The feedback from the same question to the treatment class (Figure 8) showed a similar response.

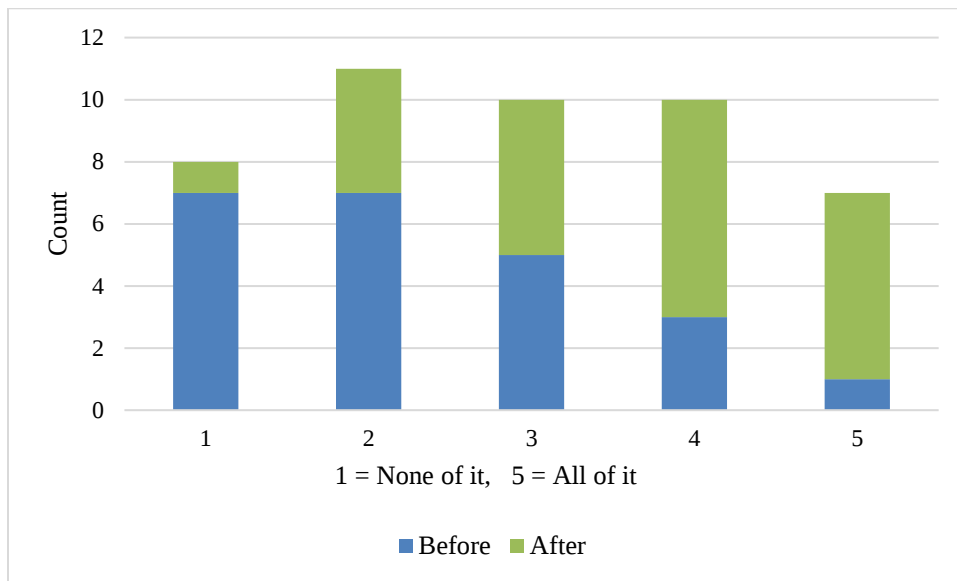


Figure 8. Treatment group responses about how much they understood about the methods of fluid systems before and after instruction, ($n=22$).

When asked what method of instruction the comparison class would like to learn fluid systems (Figure 9), only 13% of the students that answered the survey question said bookwork only, with the majority of students still wanting to receive some form of hands-on instruction. Some students made this apparent in their survey answers with quotes such as, “I would do a lot of hands-on activities to make sure we have fun while learning but also understand the subject very well” and “using the power tools really helped me see a pneumatic system.”

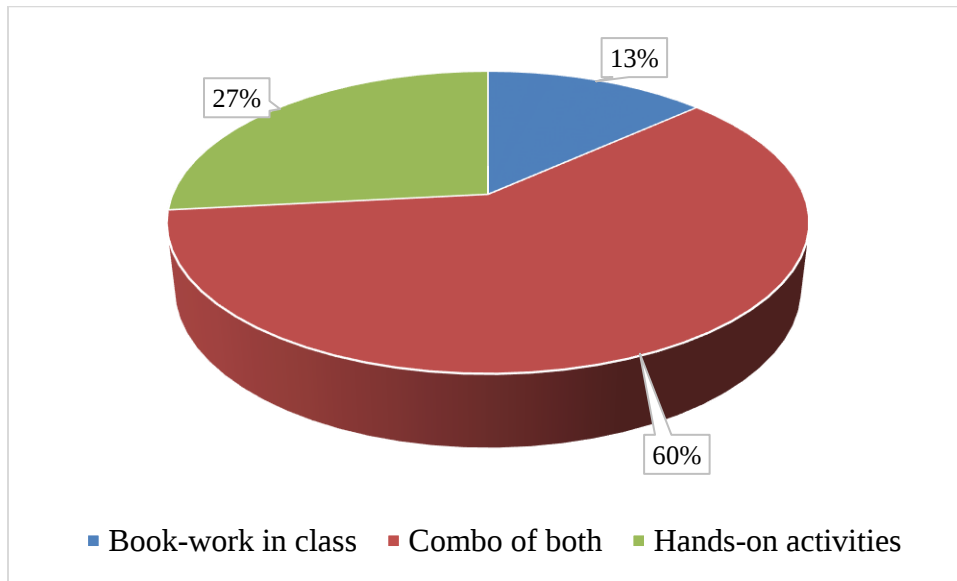


Figure 9. Survey question on choice of instruction for fluid systems comparison group, ($n=16$).

Survey data for the much larger population treatment class (Figure 8) showed confidence in students greatly improved after a week of hands-on instruction. While the comparison group showed 13% of that population preferring bookwork only, this was not mirrored with the treatment class (Figure 10) where only 9% of the population would have preferred no hands-on instruction with fluid systems. The preference of the treatment class voicing that they would prefer to receive hands-on instruction is echoed in their confidence of understanding the material after receiving hands-on instruction.

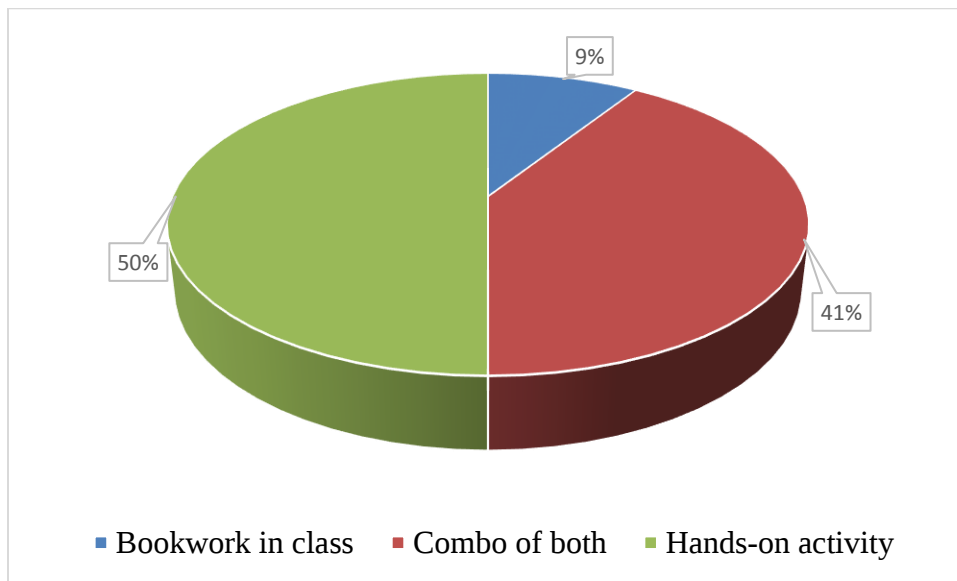


Figure 10. Survey question on choice of instruction for fluid systems for treatment class, ($n=22$).

Student journal entries for the treatment students gave feedback on their attitudes towards the activity, particularly that they enjoyed going to the automotive shop and working with hydraulic and pneumatic tools. When prompted with the journal question, “What lessons or activities did you enjoy the most during this week?”, most responses were similar to these:

- “going down to the automotive shop and learning about hydraulics”
- “going down to the automotive shop and taking off tires”
- “going to automotive and doing hands-on activities”

When asked what they least liked, then the trend again was quite clear but this time relating to any non-hands-on activity with entries such as:

- “the worksheet we had to do for homework”
- “taking the test”
- “bookwork”

- “homework on hydraulics”

The final integration project examined communication technology that focused primarily on the role of fiber optics transmitting digital signals that can then be converted over to analog signals. This project had the least amount of hands-on activities with the electronics shop, but the format stayed the same with the comparison class working with no hands-on instruction, and the treatment class working in the electronics shop. Classes could be split so that populations for both groups were nearly equal. The pre- and post-assessment scores (Figure 11) show a similar trend to that of the fluid system treatment group in that the treatment class appears to respond more to the hands-on instruction, although scores for both groups for each assessment were low in general. One other point to note is that there were two repeat students in the treatment group that had covered this material before, and that may explain why the pre-assessment score in the treatment class is higher than the post-assessment score in the comparison class.

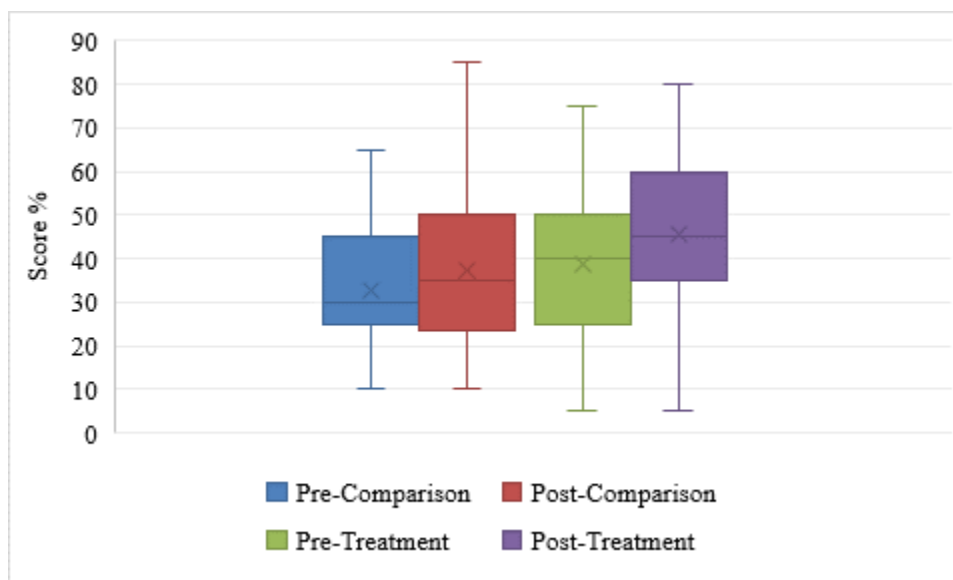


Figure 11. Pre- and post-communication assessment scores for comparison class, ($n=29$ for pre, $n=30$ for post).

The normalized gain was very low and was not statistically significant for either group with $G = 0.06$ ($p = 0.216$) for the comparison group, and $G = 0.11$ ($p = 0.0778$) for the treatment group.

Despite the low assessment scores for the comparison group, the feedback from the student surveys suggests that students felt better about the course content by the end of the framework compared to the beginning (Figure 12). However, the survey data for the treatment group showed a very clear shift towards students being a lot more comfortable with the course material after the week of integrated hands-on instruction (Figure 13).

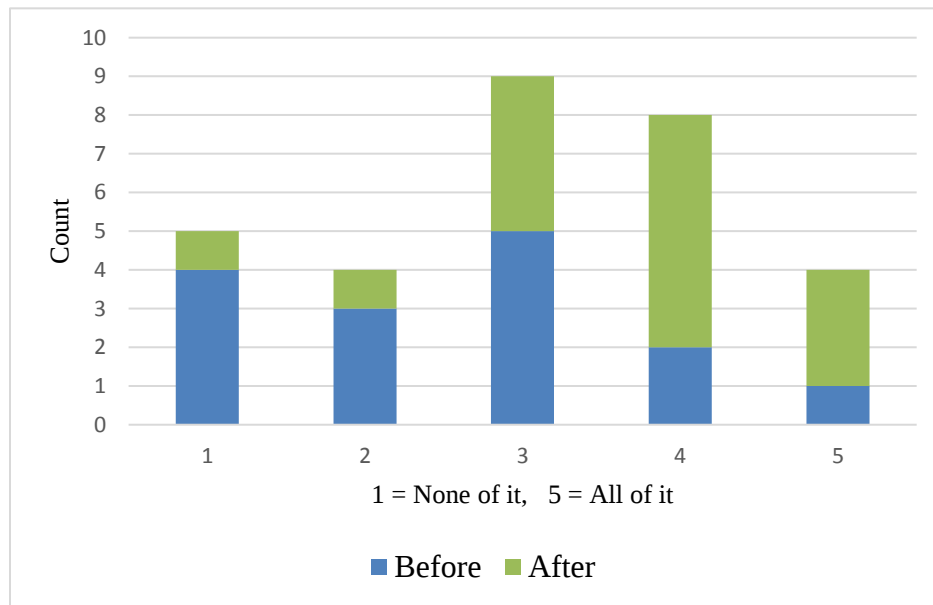


Figure 12. Comparison group responses about how much they understood about the methods of communication technology before and after instruction, ($n=15$).

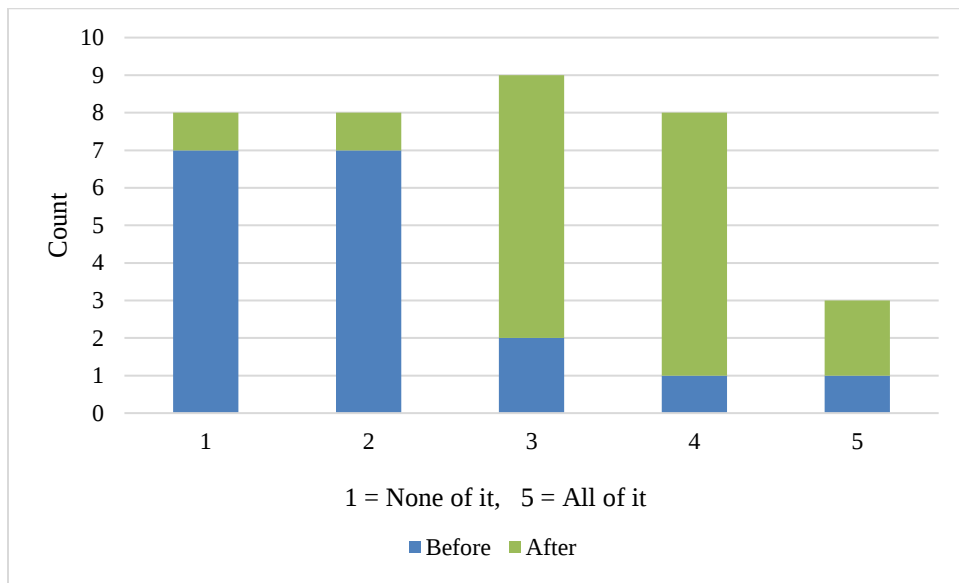


Figure 13. Treatment group responses about how much they understood about the methods of communication technology before and after instruction, ($n=18$).

Survey data from the comparison class on how to receive instruction for communication technology did not indicate a strong desire to receive just hands-on instruction (Figure 14). This was in stark contrast to the survey data from the treatment group. These students showed a strong desire to receive hands-on instruction with the communication technology framework (Figure 15). The hands-on activity covered fiber optics, which was popular with the students, and clearly gave them confidence in understanding the topic (Figure 16).

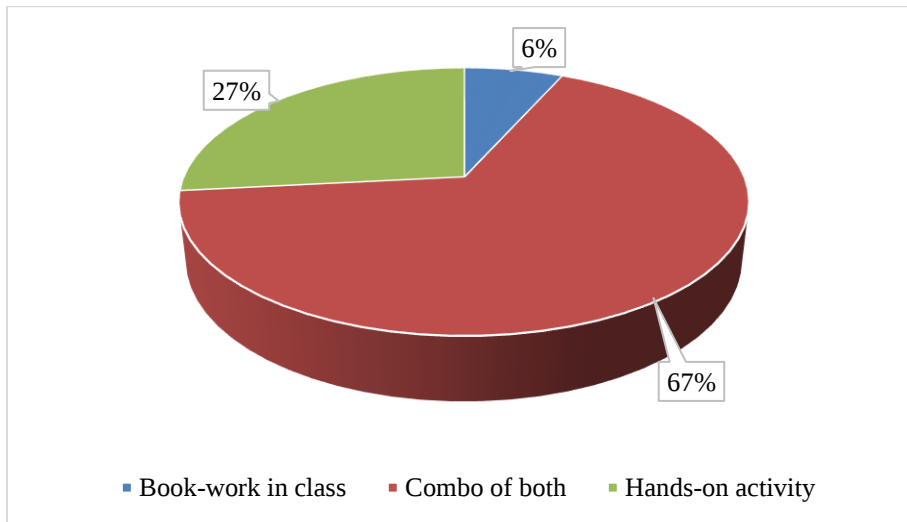


Figure 14. Survey question on choice of instruction for communication technology for comparison class, ($n=15$).

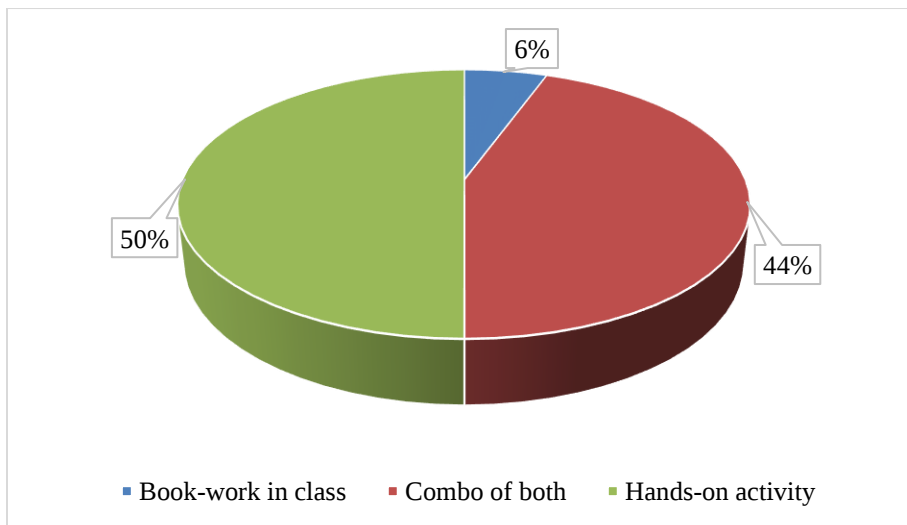


Figure 15. Survey question on choice of instruction for communication technology for treatment class, ($n=18$).

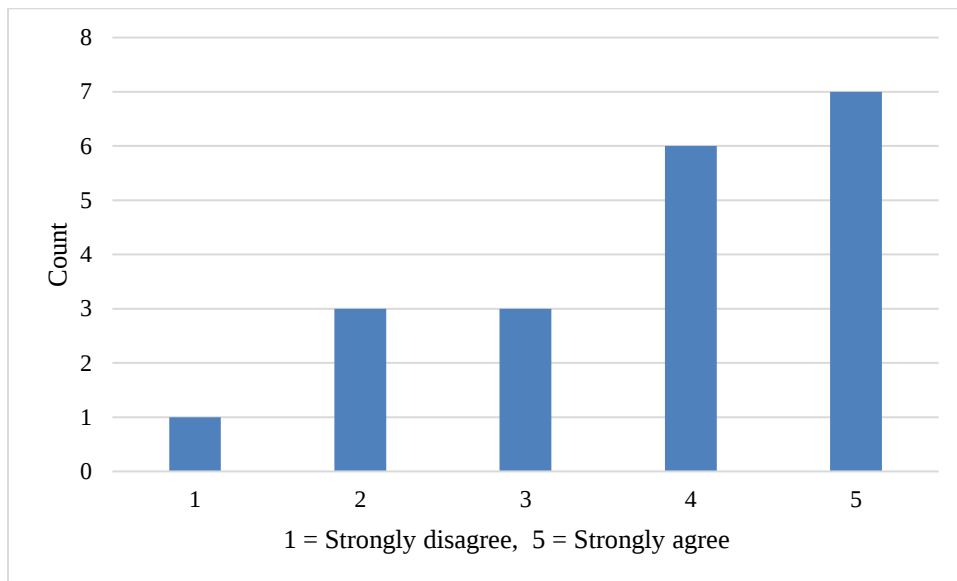


Figure 16. Treatment group survey response that hands-on instruction gave a better understanding of fiber optics, ($n=18$).

Student journal responses again illustrated that they preferred hands-on activities. When prompted as to what they liked working on the most with this framework, students typically responded with entries such as: “the lasers”, “getting lasrs [sic] to bounce of [sic] mirrors[sic]”, “working with my friend to get the lazer[sic] to hit the target” and “hearing music come from the lazer[sic] light was awesome.”

A broader comparison of the data in looking at all four integration projects shows that for all but the thermal treatment group, the post-assessment scores improved (Figure 17). The greatest gains were seen in the fluid unit, then the electrical, communication and lastly the thermal unit. For the thermal unit only the comparison group saw a gain, most likely due it being the first integration project and prone to logistical issues as well as not properly preparing the HVAC instructors with the language of the thermal systems framework. This problem was addressed in the subsequent three integration projects, and those instructors were more prepared.

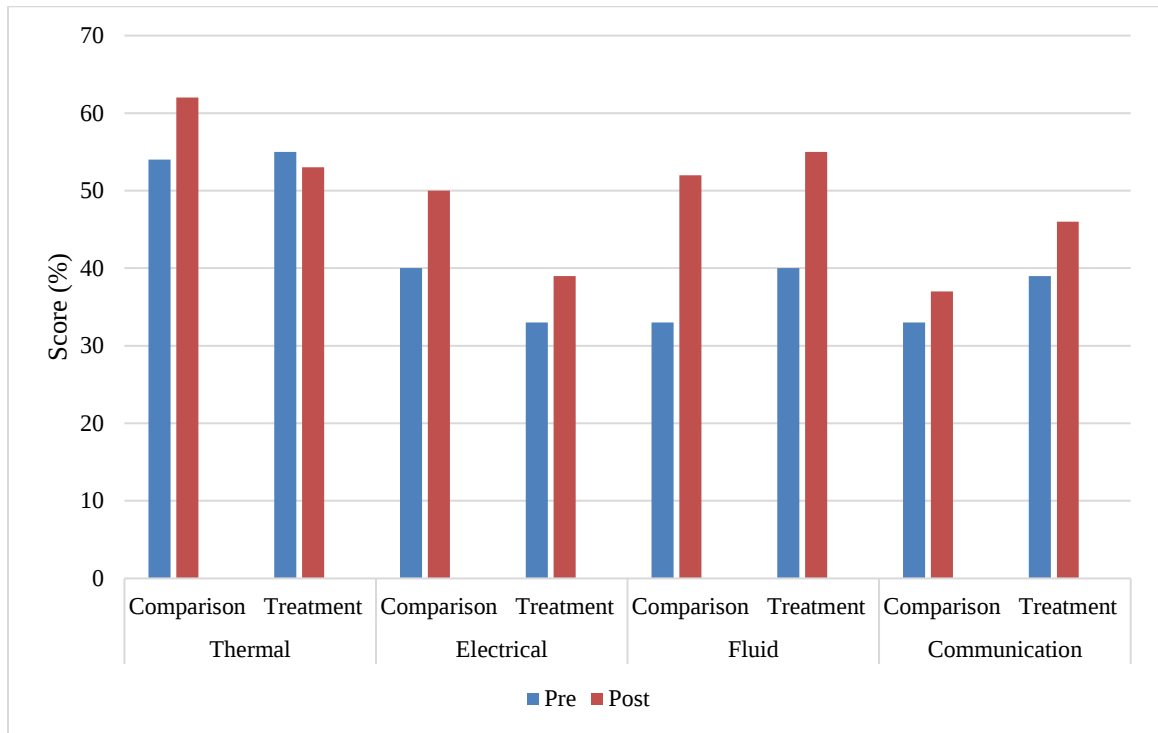


Figure 17. Pre- and post-assessment scores, ($N = 73$). Normalized gains for the comparison and treatment groups were 0.26 and -0.04 for the thermal unit, 0.18 and 0.24 for the electrical unit, 0.28 and 0.25 for the fluid unit, and 0.06 and 0.11 for the communication unit.

The assessment scores from all four integration projects were combined together to compare, as a whole, the post assessment score improvements for the comparison and treatment groups and were tested statistically (Figure 18). A *t*-test was run with a hypothesis that there would be greater improvement in post assessment scores than pre-assessment scores for the treatment classes compared to those of the comparison classes. The mean values in the post assessment scores were only 2% different between the comparison and treatment groups and the ranges overlapped significantly, between 46% and 52%. The results of the *t*-test showed the comparison pre-assessment CI = 95% (38%, 45%), the comparison post-assessment CI = 95% (45%, 52%), the treatment pre-

assessment CI = 95% (37%, 44%) and the treatment post-assessment CI = 95% (46%, 54%). With both the comparison and treatment groups mirroring similar gains in post-assessment scores, the treatment class did not perform significantly better with hands-on vocational instruction than the comparison class.

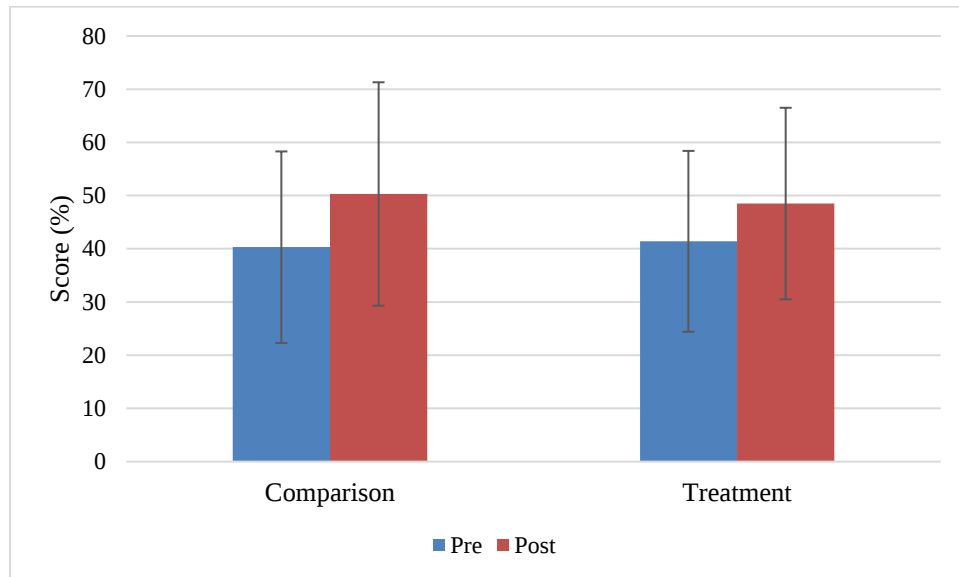


Figure 18. Mean pre- and post-assessment scores, ($N = 73$). Error bars = standard deviation of the mean.

Student interviews conducted at the conclusion of all four integration projects provided a platform for students to voice what they enjoyed and disliked, and also how they thought the concept of vocational and academic integration could improve. One interview question posed was, “What were your first thoughts when you were told we were going to be working with some of the vocational shops during this course?” The answers were, with one exception where the student said they “dreaded” it, all positive and excited:

- “I thought it was pretty cool because we were not doing it in any other classes.”

- “This should be interesting and maybe not to boring”
- “I thought oooo [sic] this will be fun”
- “I liked that idea because I like hands-on activities”.

One area of the final interview that provided some of the best insight into the impact hands-on instruction can have with students was when I asked them “After doing the written assessments, how well did the hands-on activities prepare you for them? How much did you have to rely on your notes to make sure you were properly prepared?”

Some positive responses were:

- “I think that the hands-on activities helped quite a bit and I didn’t have to rely on my notes as much as I understood everything better because of the activities”
- “The written assessments were fairly easy with all the activities that prepared us”
- “The hands-on assignments prepared me very well for the writing assignments”
- “Very well, I didn’t really have to rely on my notes”

Whereas two other students wrote:

- “the hands-on didn’t really help me and I remember the things I write so it was better”
- “It sort of helped me to prepare for them”.

Despite those comments there was a definite positive feedback from both students and vocational instructors alike, and the students were commended by the instructors with how they conducted themselves when in their shop areas.

INTERPRETATION AND CONCLUSION

At the outset of this project I asked: *How does increasing hands-on integrated activities between vocational and academic areas improve student understanding and help encourage higher-order thinking?* Although hands-on integrated activities seemed to improve student understanding, it cannot be said that it is a more effective form of instruction because the comparison group showed similar improvement. Students used higher-order thinking when they had to problem-solve during some of the hands-on activities, most notably in the design and creation of an electromagnetic generator and also to calculate the force multiplication of the hydraulic brake system with their own measurements of components. It was during those activities that certain students went above and beyond not only solving their own problems, but assisting other classmates who were struggling with the activity.

The secondary question, *How do student's attitudes towards technology/engineering change with more hands-on activities?* was answered primarily with the positive feedback seen in the surveys and student journal entries, as well as some candid replies in student interviews such as "I enjoyed working with them, it kind of made me understand some parts of the lesson more." The recognition by students when they could make the connection between what they read in their texts and what they observed that in person helped give them a positive attitude towards this class.

For the other secondary question, *How has my student's understanding changed about engineering after hands-on activities have been implemented in the classroom?*, I felt that students were able to identify with the role engineering has in problem solving by working with hands-on activities. The problem-solving aspect of the three activities:

creating an electromagnetic generator, solving force multiplication of a hydraulic brake and achieving the correct reflection angle to transmit a digital signal via a laser, allowed students to explore for themselves the concepts of the course and provides an actual solution that they can see and feel for themselves.

The treatment classes responded better to the hands-on instruction as each integration progressed, suggesting that perhaps both the students and instructors needed more time to adjust to the change in instruction style. Identifying problems in the early integration projects' instruction, such as providing all instructors with the appropriate framework language, also assisted with this. Based on the surveys, student journal and interviews, students favor hands-on instruction over bookwork.

The primary focus question, *How does increased hands-on integrated activities between vocational and academic areas improve student understanding and help encourage higher-order thinking?* can be answered to some degree. On the other hand, the secondary questions *How do student's attitudes towards technology/engineering change with more hands-on activities?* and *How has my student's understanding changed about engineering after hands-on activities have been implemented in the classroom?* have clearer resolution.

The increase in vocational hands-on activities to help instruct the technology/engineering course worked on various levels. The activities enhanced the creativity level of teaching and learning through teamwork and a sense of exploring new concepts for the first time. When students and teachers are placed in unfamiliar surroundings, this helps generate new ideas to achieve a sense of understanding, and through this understanding learning is increased both for the teacher and the student.

VALUE

The value of this project can be seen on different levels. Primarily the goal was to see if an increase in vocational hands-on learning would improve student learning and higher-order thinking. Students responded favorably to the hands-on approach and enjoyed a greater sense of discovery through observations. In addition, the project was extremely useful to the school as PRVTHS has been striving for years to see greater integration between vocational and academic departments. Data from this project can be used to work towards an increase in integration and help improve that approach as to what works well and what does not with integrated hands-on activities. Clearly, there is a lot more to consider than simply placing academic students into a vocational environment, and this project helped identify this.

As an educator I have picked up some valuable insight into how certain hands-on approaches, parlayed with the appropriate traditional teaching strategies, can keep the student engaged and eager to learn more. There is a great sense of satisfaction as an educator when you see a student working in a vocational environment that can see and apply what they learn in the classroom in that non-classroom environment.

Administrative personnel also were encouraged to see the students react in a greater integration setting between academic and vocational departments and are looking to expand on this model. Other vocational technical high schools in our state have adopted a “cluster” learning environment where vocational areas are working directly with appropriate math and science teachers to maximize the integration model. The results from this research project is to be presented to the school district, and with curriculum ever evolving it may be used to help steer further integration between

academic and vocational areas so the school can further adopt science, technology, engineering and math (STEM) teaching practices and keep up with the fast paced evolution of technical education.

The foundations of this research project have been discussed between administration and the science, mathematics and vocational director with an aim to improve upon them for next year and incorporate more departments and personnel to help maximize the impact hands-on instruction has with our student population. It is clearly a more engaging and exciting way for not only students to learn but for teachers to teach, and in a time when school enrollment across our part of the state is down, schools need to market and encourage the right students to attend PVRTHS where they can challenge themselves educationally and leave with the right tools to succeed either at further education or within the workforce.

Lastly, the true value to me was that I learned much more about my limits as an educator, and identified new strengths and weaknesses that I did not see in myself prior to undertaking this research project. I feel I have become a more effective teacher in that I have learned new skills and approaches to help teach technology/engineering to an ever changing student population with learning challenges that requires a dynamic classroom to stimulate student learning.

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APPENDICES

APPENDIX A
HVAC HEAT TRANSFER ACTIVITY

HVAC Heat Transfer

Heat.... conduction

6 inches from heating point to temp sensor, Wood dowel, steel shaft, copper pipe,
Any other materials that you may want to try?

Use heat gun to make hot at base and temp probe at other end...

Convection

Heat outside of duct work 4 inch / 6 inch and measure temp of air at one opening (add
Fan to end?)

Radiant Heat.

Build a simple Light Bulb circuit on a project board ...

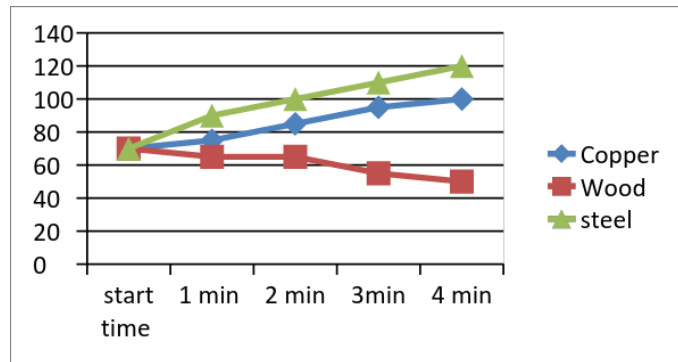
Light bulb..... Measure temp from bulb...2 inches, 4 inches, 6 inches.....

Shield temp probe and see temp rise?

Graph each experiment,,,,,,,,

Have a minimum of 3 graphs one for each heat transfer method

Temperature rise in materials..... Air, pipes etc.



Time VS Temperature

Use Vice as a Heatsink

Explain how a Heatsink works?

Make ICE and measure temp of Ice just out of freezer and then after a few minutes
Measure temp in Shop..... Calibrate or check calibration of the temperature probes on our meters..

What is the HOTTEST SPOT in the SHOP...

WHAT is the COLDEST SPOT in the shop.....

Make Ice in the refrigerator without looking in the refrigerator....how can you be 100% sure it is ice before opening the refrigerator.

Weight of water / Weight a Gallon of Water.....

Weight of AIR / Weight AIR

PSIG.... Start using Manifold Gauge...

Used to read pressures in refrigeration systems

APPENDIX B
ELECTROMAGNETIC GENERATOR ACTIVITY

Lesson 3: Dynamos

Adopted/Revised From

http://amasci.com/coilgen/generator_1.html
www.teachingengineering.org

Grade Level

6-12

Objectives

- Construct dynamo electric generator
- Troubleshoot and reconstruct for the most efficient design
- Explain how electricity is generated by identifying the common component

Overview

Students observe magnetic properties of electricity flowing through a wire, construct a generator, troubleshoot until it is functioning.

Materials

Opening Activity

- Tape
- One Magnetic compass per group
- One 6" wire
- One AA battery per group

Generator:

- Four ½"x1"x2" rectangular ceramic magnets per group (i.e. Radio Shack #64-1877) • One roll of enamel-coated magnet wire, 200 feet 30 gauge (i.e. Radio Shack part # 2781345)
- One 12V DC piezo buzzer, 3.0-28V DC, 5mA (i.e. Radio Shack 273-0060)
- One heavy duty corrugated cardboard strip 3.5" x 10" (from recycled box) per group
- One 3-4" nail per group
- One multimeter per group (i.e. Kid Wind #H0022)
- Sandpaper – fine grit, ½ sheet per group
- One ruler per group
- One rubber band per group
- Adhesive tape

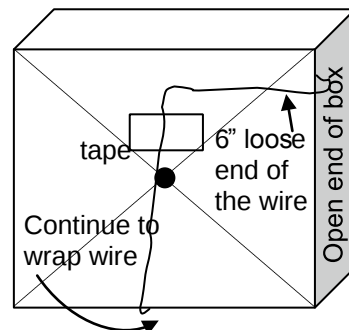
Investigation

We are going to an electric generator and figure out what is producing electricity. Students will use a AA battery to explore the induction effect between magnetic and electric fields and assess how this current affects the magnetic needle of a compass:

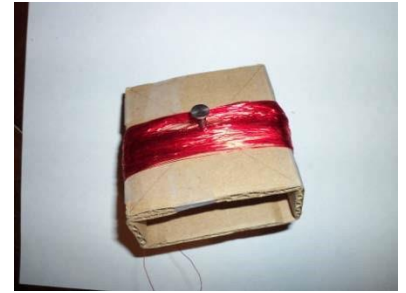
1. Divide the students into four groups.
2. Hand each group 1 AA battery, 6" length of insulated wire, tape, and a compass.
3. One student will tape one end of the wire to the positive pole of the battery.
4. One student will hold the compass level so that the needle is parallel to the floor and everyone in the group can see it.
5. The student with the battery will hold the battery directly under the compass.
6. A third student will take the dangling wire and encircle the compass with it, holding it by its insulation and bringing the exposed wire end just up to the negative pole of the battery.
7. When everyone is watching the compass needle, the student with the wire will briefly touch the negative pole of the battery. The compass needle will jump as it reacts to the changed electric field. Do this several times to be sure of the effect. **Caution: Do not hold the wire against the battery for more than a fraction of a second. The battery and wire will become very hot quickly!**

Generator:

1. Using the template following this lesson plan, cut the corrugated cardboard outer rectangle (10"x3.5"). This is called the housing.
2. Score the four inner lines with the edge of the scissors.
3. Fold the rectangle at the scored lines, using the ruler as a brace to get straight edges.
4. Panel #5 will fold over Panel #1. Tape to secure.
5. Tape all edges of your open ended box to reinforce corners.
6. Mark your box at the center point, using your ruler to find the midpoint (draw a line diagonally corner to corner in each direction, and the midpoint is at the intersection of the two lines) as indicated by the template's black circle.
7. Use the nail to carefully poke a hole at the midpoint on both sides of the box. Reinforce the underside of the box with your hand while poking the hole so that the cardboard is not bent during this process. Poke a hole directly opposite on the other side of the box. Don't poke your hand!
8. Insert the nail into both holes and push the cork on the nail's sharp end. The cork must not rub on the box as the nail spins.



9. The wire will be wrapped around the housing, and not over the open ends of the box. Each end of the wire will be attached to a buzzer. Place 15cm (6") of wire inside the box to use later to attach your buzzer. Tape the lead wire securely to the outside of the box (see diagram).
10. Lightly wrap the wire around the outside of the cardboard housing about 300 times until you have used all the wire. Wrap the wire on either side of the nail. Do not wrap tightly, because the pressure will crush the box.
11. Leave 15cm (6") of wire to attach the buzzer.
12. Sandpaper 1" of the ends of the wire to remove any enamel insulation.
13. Sandpaper 1" of the buzzer wires to remove any insulation (if needed).
14. Securely twist the wire from the generator to one end of the buzzer wire. Double check that the wire is secure.
15. Securely twist the other wire from the generator to the other buzzer wire. Double check that the wire is secure. You can secure the buzzer to the housing with a rubber band as long as it does not restrict the movement of the nail or magnets.
16. Place the magnets around the nail.
17. Make two small spacers out of cardboard for the magnets the thickness of the nail and the width of the magnet. The length of the spacers will be less than half the length of the magnet. This will stabilize your magnet assembly.
Insert between the two magnets on either side of the nail. The nail/magnet assembly needs to spin smoothly. If not, you need to alter the design, keeping the magnets as close to the inside of the box as possible. You can tape the spaces in place.
18. Spin your nail and magnet housing. If you don't hear the buzzer, spin the nail and magnet house in the opposite direction. (Why?) Make sure that the wire from the buzzer is touching the wrapped wire and not the insulated part of the wire.



Template for Generator #1 corrugated cardboard rectangular housing for dynamo.

Cut out the large outer rectangle. Score on inner lines where indicated in panels #2 and #4 and fold into a box with open top and bottom. Tape panel #5 to panel #1.
Black circles are centered for inserting nail on panel #1 and #3

APPENDIX C

HYDRAULIC BRAKE ACTIVITY WORKSHEET

NAME: _____

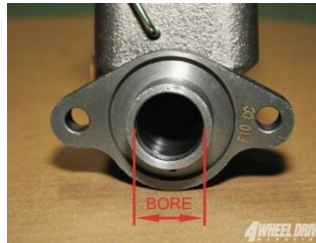
DATE: _____



Brake System Hydraulics

INSTRUCTIONS: This is a 2 part exercise. For the first part you will be measuring brake system hydraulic components. The second portion is going to consist of using formulas to compute Pascal's Law.

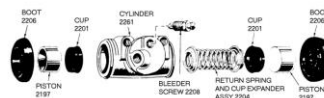
PART 1: Component Measuring



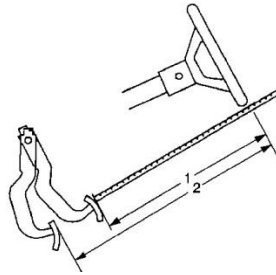
1. Measure the diameter of the master cylinder bore in inches square:



2. Remove the piston and measure the diameter of a brake caliper:



3. Measure the diameter of the rear brake wheel cylinder: _____



4. Measure the brake pedal distance static and depressed as shown in the picture above. The difference between measurement 1 and 2 represents the brake pedal travel. Take this value and divide it by 2 (to compensate for the brake pedal lever). This value represents D1 (distance the master cylinder piston travels): D1 = _____

PART 2: PASCAL'S LAW CALCULATIONS

F = Force / P = Pressure / A = Area

$$F = P \times A$$

5. Using a predetermined force value of 200 ft/lbs as your input (this represents the drivers force on the brake pedal), calculate what the hydraulic system pressure will be using Pascal's law for the Master Cylinder (A1): _____
6. Now that you have your input figures it's time to calculate how much output force the brake system will generate. Using the pressure data from question 5, calculate the output force of the following components:
- A. Brake caliper: _____
- B. Wheel cylinder: _____

D = Distance / F = Force

$$D_2 = \frac{F_1 \times D_1}{F_2}$$

7. Use the above formula to calculate the distance the pistons will travel in the components below. Use your value from question 4 as distance 1 (this is how far the master cylinder will travel):
- A. Disc Brake Caliper piston: _____
- B. Wheel Cylinder piston: _____

8. Why does the brake pedal travel further than the disc brake caliper piston? __

9. Describe the relationship between force and distance in a hydraulic brake system: _____

APPENDIX D
EXAMPLE OF STUDENT WORK

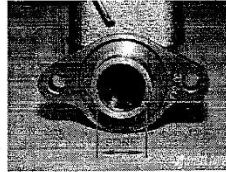
NAME: _____

DATE: 4/8/16

Brake System Hydraulics

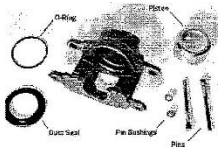
INSTRUCTIONS: This is a 2 part exercise. For the first part you will be measuring brake system hydraulic components. The second portion is going to consist of using formulas to compute Pascal's Law.

PART 1: Component Measuring



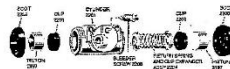
1. Measure the diameter of the master cylinder bore in inches square: 1 1/4 in 3/4 in

1.22 in



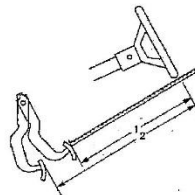
2. Remove the piston and measure the diameter of a brake caliper: 2 1/2 in

4.90 in



3. Measure the diameter of the rear brake wheel cylinder: 1 1/4 3/4 in

1.22 in



$\pi \cdot r^2$

4. Measure the brake pedal distance static and depressed as shown in the picture above. The difference between measurement 1 and 2 represents the brake pedal travel. Take this value and divide it by 2 (to compensate for the brake pedal lever). This value represents D1 (distance the master cylinder piston travels): D1 = 3/4 in

44 in

PART 2: PASCAL'S LAW CALCULATIONS

$$F = \text{Force} / P = \text{Pressure} / A = \text{Area}$$

$$F = P \times A$$

5. Using a predetermined force value of 200 ft/lbs as your input (this represents the drivers force on the brake pedal), calculate what the hydraulic system pressure will be using Pascal's law for the Master Cylinder (A1): 200 / 1.22 = 163
6. Now that you have your input figures it's time to calculate how much output force the brake system will generate. Using the pressure data from question 5, calculate the output force of the following components:

- A. Brake caliper: 798 = F
- B. Wheel cylinder: 198 = F

$$D = \text{Distance} / F = \text{Force}$$

$$D_2 = \frac{F_1 \times D_1}{F_2}$$

$$D_2 = \frac{798 \times 1.44}{198}$$

7. Use the above formula to calculate the distance the pistons will travel in the components below. Use your value from question 4 as distance 1 (this is how far the master cylinder will travel):
- A. Disc Brake Caliper piston: 1.7 in
- B. Wheel Cylinder piston: 1.7 in

8. Why does the brake pedal travel further than the disc brake caliper piston? most of the force is put into the brake pedal.
9. Describe the relationship between force and distance in a hydraulic brake system: you put a force into a brake pedal

APPENDIX E
STUDENT JOURNAL

Student Journal

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

- 1. What area of the course have you been working on recently and what framework does that come under?**

Entry:

- 2. What lessons or activities did you enjoy the most during this framework?**

Entry:

- 3. What lessons or activities did you least enjoy during this framework?**

Entry:

- 4. What concepts did you find easiest to learn?**

Entry:

- 5. What concepts did you find hardest to learn?**

Entry:

APPENDIX F
STUDENT SURVEY QUESTIONS

Fluid Systems

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way

1. **Before the class activities this week, how well did you understand the methods of fluid systems?**

Mark only one oval.

	1	2	3	4	5	
None of it	☐	☐	☐	☐	☐	All of it

2. **After the class activities this week, how well did you understand the methods of fluid systems?**

Mark only one oval.

	1	2	3	4	5	
None of it	☐	☐	☐	☐	☐	All of it

3. **How confident do you now feel about answering MCAS questions on fluid systems?**

Mark only one oval.

	1	2	3	4	5	
Not confident	☐	☐	☐	☐	☐	Very confident

4. **In which way would you prefer to learn about fluid systems?**

Mark only one oval.

- ☐ Book-work in class
☐ Hands-on activities
☐ Combination of both book-work and hands-on

5. **The automotive shop hands-on activity gave you a better understanding of fluid systems.**

Mark only one oval.

	1	2	3	4	5	
Strongly disagree	☐	☐	☐	☐	☐	Strongly agree

APPENDIX G

STUDENT INTERVIEW QUESTIONS FORM

Integrated Interview

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

1. What were your first thoughts when you were told we were going to be working with some of the vocational shops during this course?

2. Did you enjoy working with the shop instruments or did you find them a little overwhelming? If they were overwhelming at first, did it get any easier the longer we were there?

3. With regards to the hands-on activities, did you feel there was enough hands-on time in the shop or too little? Were the activities too technical, or not technical enough? Please explain your reasoning.

5/13/2016

Integrated Interview

4. After doing the written assessments, how well did the hands-on activities prepare you for them? How much did you have to rely on your notes to make sure you were properly prepared?

5. Were the hands-on activities properly explained to you and were the materials sufficient? If not, how so?

6. Should Pathfinder be doing more integrated teaching involving both the academic and vocational shops in subjects such as science? Why or why not?

7. Lastly, describe in your own words what you did in the shops during this class. What did you get, (or not get), out of it, what worked and what didn't? Would you say it was a positive experience? If you could make any changes, what would they be?

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 Google Forms

APPENDIX H

SAMPLE OF MCAS MULTIPLE CHOICE QUESTIONS

Electrical Systems MCAS Questions

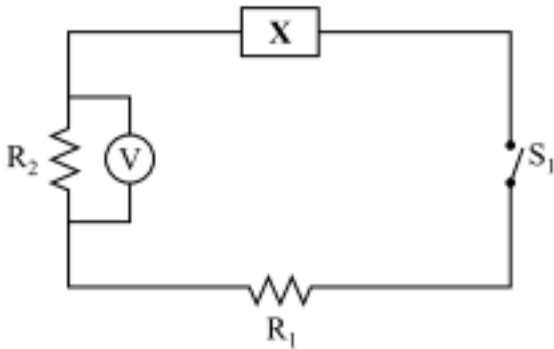
1. Which of the following devices **most likely** operates on alternating current?

- A a cell phone
- B a flashlight
- C a laptop computer
- D a microwave oven

2. Which of the following would be **most** affected if the temperature of a 20 ft. piece of 14-gauge copper wire were increased by 30°C?

- A the melting point of the wire
- B the electrical resistance of the wire
- C the signal processing speed of the wire
- D the direction of current flow within the wire

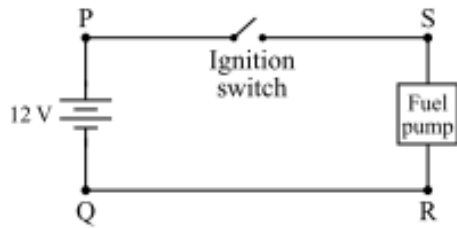
3. The drawing below shows a series circuit.



This series circuit operates when the switch is closed. Which of the following is **most likely** represented by X?

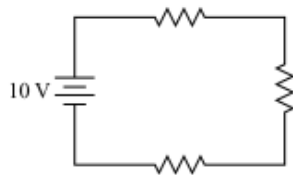
- A source
- B ground
- C transistor
- D ohmmeter

4. The diagram below represents a circuit to a fuel pump in a car. The ignition switch is turned off.



This fuel pump may have an internal short circuit. At which two points should an ohmmeter be connected to measure the resistance of the fuel pump?

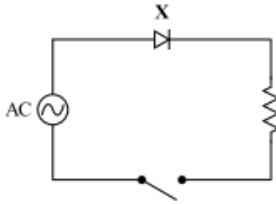
- A P and S
 - B Q and P
 - C R and Q
 - D S and R
5. A series circuit is shown in the diagram below.



What is the total resistance of the circuit if the current is 2 A?

- A 5.0 Ω
 - B 6.6 Ω
 - C 15 Ω
 - D 60 Ω
6. In an electrical circuit, which of the following has the **greatest** direct effect on the resistance of a metal conductor?
- A the temperature of the conductor
 - B the malleability of the conductor
 - C the color of the conductor
 - D the age of the conductor

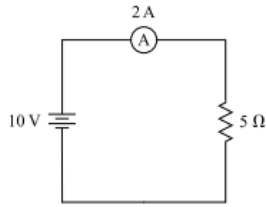
7. The diagram below shows an electrical circuit.



Which of the following statements describes a function of component **X** when the switch is closed?

- A Component **X** turns the circuit on and off.
 - B Component **X** supplies energy to the circuit.
 - C Component **X** uses a low current to control a higher-current circuit.
 - D Component **X** allows electrical current to flow in only one direction.
8. Which of the following statements accurately describes electrical circuits?
- A Only AC circuits can transmit electrical energy.
 - B Only DC circuits can transmit electrical energy.
 - C Current in AC circuits flows in both directions.
 - D Current in DC circuits flows in both directions.
9. The voltage across a resistor in a circuit is 6 V and the current is 0.25 A. What is the resistance?
- A 0.04 Ω
 - B 1.5 Ω
 - C 9 Ω
 - D 24 Ω
10. Which of the following statements describes an advantage of AC electricity over DC electricity?
- A AC is found in most low voltage operations.
 - B AC is provided as strong, short bursts of electricity.
 - C AC transforms easily to higher or lower voltage levels.
 - D AC travels in one direction, avoiding power supply interruptions.

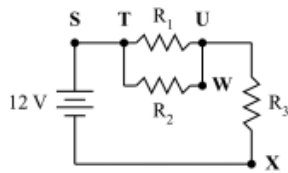
11. Lupe built the simple circuit shown below.



Lupe modifies this circuit by decreasing the voltage of the battery by one-half. In order to keep the amount of current flowing through the circuit the same as it was before, which other change must Lupe make to the circuit?

- A** She must add a switch.
- B** She must increase the resistance.
- C** She must decrease the resistance.
- D** She must remove a section of wire.

12. The diagram below shows a circuit with three resistors.



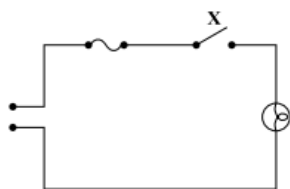
At which of the following points should the two leads of a voltmeter be placed to measure the voltage across R_1 ?

- A** at points U and W
- B** at points S and X
- C** at points S and T
- D** at points T and U

13. A homeowner uses an extension cord to provide power to exterior holiday lights. A strand of holiday lights consists of 100 light bulbs wired in parallel. Which of the following actions will have the **greatest** effect on the resistance of the extension cord?

- A connecting several strands of lights to the extension cord
- B plugging the extension cord into a ground-fault circuit interrupter outlet
- C operating an indoor appliance while providing power to the extension cord
- D leaving several burned-out bulbs in a strand of the lights connected to the extension cord

14. The diagram below shows a typical household electrical light circuit.



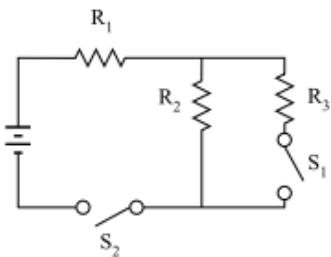
What is the **most likely** function of the component marked **X** in this circuit?

- A to open and close the circuit
- B to produce voltage for the circuit
- C to protect the circuit from excess current
- D to ensure that current flows in only one direction

15. A homeowner uses an extension cord to provide power to exterior holiday lights. A strand of holiday lights consists of 100 light bulbs wired in parallel. Which of the following actions will have the **greatest** effect on the resistance of the extension cord?

- A connecting several strands of lights to the extension cord
- B plugging the extension cord into a ground-fault circuit interrupter outlet
- C operating an indoor appliance while providing power to the extension cord
- D leaving several burned-out bulbs in a strand of the lights connected to the extension cord

16. A diagram for a circuit with two switches, S_1 and S_2 , is shown below.



If S_1 is left open and S_2 is closed, which resistors will be in series?

- A R_1 and R_2 only
- B R_1 and R_3 only
- C R_2 and R_3 only
- D R_1 , R_2 , and R_3

17. A teacher performs an experiment for a group of students. The teacher uses long, thin copper wires to connect a battery to a small light bulb. The teacher then applies heat to the copper wires. The students observe that the light bulb becomes dimmer. As the wires cool, the students observe that the light bulb becomes bright again. Which of the following relationships is the teacher most likely trying to demonstrate?

- A Light affects heat.
- B Wire material affects voltage.
- C Temperature affects resistance.
- D Wire diameter affects transformation.

18. Which of the following statements **best** compares direct current (DC) and alternating current (AC)?

- A AC flows in only one direction, and DC flows in both directions.
- B DC flows in only one direction, and AC flows in both directions.
- C AC comes directly from a power plant, and DC comes from a magnetic field.
- D DC can maintain a constant voltage over time, and AC loses voltage over time.

19. Maria needs to measure the amount of current flowing through a closed circuit. Which of the following instruments should she use for this task?

- A** ammeter
- B** hygrometer
- C** ohmmeter
- D** voltmeter

20. In a circuit, an electrician replaces a 4 ft. section of wire with a wire that has a larger diameter. This change in wire diameter will cause which of the following results?

- A** The current in the new wire section will be less than in the original wire.
- B** The resistance of the new wire section will be less than that of the original wire.
- C** A greater power loss in the circuit will occur because of the new wire section.
- D** A greater voltage drop across the circuit will occur because of the new wire section.

APPENDIX I
STUDENT INTERVIEW QUESTIONS

STUDENT INTERVIEW QUESTIONS

- **Introducing questions:** “Can you tell me about....?”, “Do you remember an occasion when...?” “What happened in the episode mentioned?”...
- **Follow-up questions:** Direct questioning of what has just been said, nodding, “mm”, repeating significant words
- **Probing questions:** “Could you say something more about that?”, “Can you give a more detailed description of what happened?”, “Do you have further examples of this?”
- **Specifying questions:** “What did you think then?” “What did you actually do when you felt a mounting anxiety?”, “How did your body react?”...
- **Direct questions:** “Have you ever received money for good grades? When you mention competition, do you then think of a sportsmanlike or a destructive competition?”
- **Indirect questions:** Projective questions such as ‘How do you believe other pupils regard the competition of grades?’
- **Structuring questions:** indicating when a theme is exhausted by breaking off long irrelevant answers: “I would now like to introduce another topic:...”
- **Silence:** By allowing pauses the interviewees have ample time to associate and reflect and break the silence themselves. With significant information.

Interpreting questions: “You then mean that....?” “Is it correct that you feel that...?” “Does the expression.... Cover what you have just expressed?”

APPENDIX J
INSTITUTIONAL REVIEW BOARD STATEMENT



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

960 Technology Blvd. Room 127
 c/o Immunology & Infectious Diseases
 Montana State University
 Bozeman, MT 59718
 Telephone: 406-994-6783
 FAX: 406-994-4303
 E-mail: cherylj@montana.edu

Chair: Mark Quinn
 406-994-5721
 mquinn@montana.edu
Administrator:
 Cheryl Johnson
 406-994-6783
 cherylj@montana.edu

MEMORANDUM

TO: David Wilson and Peggy Taylor
FROM: Mark Quinn, Chair *Mark Quinn CJ*
DATE: November 9, 2015
RE: "The Effects of Increased Vocational Hands-On Instruction in an Academic Science/Technology Classroom" [DW110915-EX]

The above research, described in your submission of November 9, 2015, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- X (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- _____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- _____ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- _____ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- _____ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.