ETEC 543 Action Research Final Project, fall 2017

The performance effects of guided experiential learning for students in the planning and wiring of electrical circuits

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Abstract

The action researchers of this study cited a problem in traditional community college lectures on electricity and electronics as related to the construction of circuits where wiring methods were not effectively taught. They proposed a solution to this deficiency, called the Leighton-Graham Method (LGM) of guided, hands-on, experiential learning that was tested in this mixed-methods quasiexperimental study. Two separate courses of beginning electricity students participated. A control group of 11 students and a treatment group of 19 students were pre, and post-tested using a hands-on wiring performance test to ensure the groups were roughly equal in beginning wiring skill levels. Scores were assigned based on a performance rubric. An exit survey was administered to each group after the post-tests, to gather qualitative information to help clarify the quantitative post-test results. Even though the researchers admitted that the participant groups were small, they stated that their LGM appeared to be what enabled the treatment group to achieve 100% success on the hands-on wiring post-test, as compared to only 45% in the control group, and in 34% less time than the control. While both groups contained roughly the same number of participants with a history of work experience that included wiring, only those participants in the control group could wire their circuits properly during the post-test. While the researchers felt that their LGM had made a significant difference in the performance between the two groups, they also stated that more research needed to be conducted.

Introduction

Community colleges work closely with local industries that hire their graduates. "Career and Technical Education (CTE) has traditionally been viewed as the cornerstone of workforce preparation" (Asunda, 2012). Our topic is: ***The performance effects of guided experiential learning for students in the planning and wiring of electrical circuits.*** Therefore, the goal is to make these CTE college electrician students more marketable by learning this new information about wiring electrical circuits, in new ways. Recently, twenty of the largest employers in America jointly requested that electrician students be taught how to wire electrical circuits more effectively, because this skill is becoming a serious deficiency in industry. This area of study has not been taught through traditional methods in community colleges, but only in university engineering schools. So, industrial technicians may never receive this training. Therefore, we explored how to translate the Leighton-Graham Method (LGM) of circuit planning and wiring, from electronics over to the electrical trades, to accomplish this goal, set by industry leaders.

To test our ideas, we envisioned having two beginning electrical courses sampled, to see if the LGM might be an effective training modality. The challenges that were encountered were not having enough of the identical devices for each student to work individually, with the same hardware. So, substitution of functionally equivalent parts was required. Most lab projects are done in teams at our college, when in normal lab situations, so that fewer supplies are required. Another problem was having enough repeat students in classes for teaching and testing on consecutive nights, using the same students. This limitation would reduce the number of qualified participants to maintain continuity in the training and testing. A goal was set to see if the treatment group, receiving the hands-on LGM training in guided, hands-on, experiential

lecture/demonstrations would benefit more than the control group who only received the traditional training.

This action research report, will illustrate our findings from the quantitative and qualitative data collected. At the outset of this study, it was hoped that it would demonstrate that the alternate LGM training for the treatment group would enhance their overall performance and understanding of the new methods to be learned, as compared to just the traditional lecture the control group would receive.

This report will also show what we discovered through literature review, the methodology we employed, statistical findings from our research of our two groups, as well as the materials we created and implemented for the treatment group, all of which can be found in the appendix section of this report.

Literature Review

The literature review for the project covered many aspects of our scope of interest. According to Burgher (2015) "Results indicate that 72% of students receiving the hands-on (Desktop Learning Modules) DLM treatment thought it helped more than lecture; of those receiving lecture,…"(p. 44). This came from the Burgher article, "Implementation of a Modular Hands-on Learning Pedagogy: Student Attitudes in a Fluid Mechanics and Heat Transfer Course". At the IEEE conference in India, Pranab et al (2014) gave a paper on "A novel wiring planning technique for optimum pin utilization in Digital Microfluidic Biochips". Illustrating the universal wire routing and planning can be transferred to full-scale electrical circuits, such as we are proposing to optimize, using the LGM for the planning and wiring of electrical circuits. This further adds to the scaffold of supportive information mentioned in the previous Burgher article

about the effectiveness of hands-on training experiences. In reading Hyun's et al article "Students' Satisfaction on Their Learning Process in Active Learning and Traditional Classrooms" helped to substantiate our premise that our students do better with hands-on activities rather than straight lecture classes. The results of their study show that ALEs increase student satisfaction directly, and served to boost student learning actions productivity and retention positively. So, the guided learning experiences of the LGM of planning and wiring electrical circuits both satisfies our CTE hands-on learners, and engages them in their own natural learning styles, which makes the experience even more meaningful and memorable for them. "Teaching for Engagement: Part 3: Designing for Active Learning" by Hunter (2015) outlined the theory behind his rationale on the classroom Active Learning Environment (ALE) an subsequent research, using case-based methods of teaching and problem learning, as he termed it. He went on to describe means of facilitating contemporary technologies in traditional classrooms to support ALE. Active Learning Environments for CTE students means that hands-on activities will be included to both establish and maintain full engagement with these hands-on learners, but also so true that learning may begin through tactile feedback from the objects being manipulated, as though the devices are revealing their secrets to the learners via an immersive communications link, akin to telepathy for these learners—that is, experiential learning. Furthermore, the memory retention of first-hand experiences, such as these are more lasting and personally internalized by hands-on learners. Cattaneo (2017) addressed the difficulty in dealing with a transition from traditional transmission-based lectures to Active Learning Environments (ALEs) in his paper "Telling Active Learning Pedagogies Apart: From Theory to Practice". He believes that inquiry and discovery are strong tools for learning that are rooted in student projects, where hands-on, discovery learning, and experiential learning modalities naturally

occur. He classified five ALE pedagogies that are based on six constructivist ideas, related to PBL. This article reflects our findings, where Project Based Learning (PBL, not to be confused with problem-based learning) as a benefit to our treatment group, as compared with only the traditional lectures transmitting information to our control group. Asunda (2012) focuses on STEM Literacy as the CTE cornerstone of our modern economy, and the skills needed to keep it growing, which is right on target for our research project. We researched more articles that can be found in the Appendix-A.

Methodology

Action Research Questions

Will guided experiential learning practices in the planning and wiring of electrical circuits impact student hands-on performance skills? If so, what will the impacts be?

Data Collection

We collected both Quantitative (quasiexperimental), and Qualitative (voluntary answers to survey forms), to triangulate the data for better understanding of the results. We used the pretest / posttest method of comparative assessment. Community College CTE students in each of two beginning electrical classes were tested and compared. Prior to any instruction, both groups took a hands-on performance based pretest to assess their entry-level abilities, in the previous class, for 3-hours duration. One classroom of students served as the control group with 11 participants that did not receive the treatment, but received the traditional training in electricity and circuits, for 3-hours duration. The 19 participants of the treatment group classroom received the alternate training through the use of the LGM guided experiential learning instruction for planning and wiring of electrical circuits for the same 3-hour duration.

True-random selection of participants in each group will not be possible. We used opportunity-selection of participants, resulting from chance-enrollments in each class. At the end of training, both groups of students were evaluated based on the same hands-on performance test that measured the accuracy and effectiveness of their skills. For our quantitative results, there were two measures of hands-on performance (1) the length of time each student took to plan and wire the circuitry correctly; (2) the number of wiring errors each student exhibited, prior to getting the assigned circuit wired to properly function. Successful demonstrations to the instructor/evaluator were used as evidence of proper functionality. Failures were recorded as error incidents for each anonymous student I.D.; and, each student then needed to repair the errors, iteratively, until successful operation was achieved and recorded. The hands-on performance posttest at the end of all instruction was used to calculate the change in the learners' performance skill levels. After this posttest was administered and collected, a Qualitative exit survey questionnaire was given to students, so that their feedback could be later analyzed to help the researchers better understand the Quantitative data (and revisions made, as needed, based upon later reflection). This survey was comprised of a total of 15 open-ended questions, with four Likert-type questions—19 in all. See Appendix-B (primary and supplemental online survey questionnaire links); see Appendix -C for instruments used to gather data, record responses; see Appendix -D for analysis of the results; see Appendix-E for general handouts; see Appendix -F for the LGM materials the treatment group received throughout the study; and see Appendix -G keys to wire-listings and planning.

Data Analysis

As part of a holistic process to assure validity and reliability of test data, both pretest and posttest data was collected and judged to be relatively equal between the two groups, so that the performance results of the hands-on posttest could be generalized to represent a much larger

population of students. If the initial study questions had been translated into hypotheses, then chi-squared statistical methods could have been effectively used to compare the results through the corresponding p-value, to demonstrate significance in outcomes between the two groups. But, because questions were used instead, answers were sought to satisfy them using educated judgment, guided by the resulting statistical values of the two groups. Mean values and low-population standard deviation values were calculated for each data set. Then, like values from each group were compared from the quantitative data gathered of the final hands-on performance test scores. To triangulate (the text calls it polyangulation) the results of the qualitative survey questions and answers were categorized into similar groups. Then, the responses were tallied as a frequency of occurrence, in percentages of total similar responses, having been further categorized as positive, neutral, or negative in nature. This is where the participants' previous wiring experience numbers, and other added information emerged to clarify aspects of the meaning of the quantitative data.

Results

While both groups contained roughly the same number of participants (control=5; treatment=6) with a history of work experience that included wiring, only those participants in the control group could wire their circuits properly during the hands-on performance posttest. In the wiring performance posttest, quantitative analysis showed that only five out of 11, or 45% of control group participants successfully got their circuits wired to function properly within the allotted time of three hours. Of the successful five in the control group, the average time required for success was 139 minutes. Average point-scores, according to the grading rubric in Appendix-D, were as follows: the average control group score was 39%, with a standard

deviation of 22%; while the average treatment group score was 89.5% with a standard deviation of 6.7%.

Qualitative data from open-ended and Likert-scale question responses on the exit surveys were grouped together into coded categories. These categories were characterized as: enjoyment; adequacy of instruction; improvement of training; hands-on learning; post-test self-performance assessment; and previous wiring experience. From those surveys, the control group indicated that 10 of their 11 (91%) members were hands-on learners, as compared to 19 out of 20 (95%) in the treatment group. The other responses to each of the qualitative categories were subsequently judged to be: positive, neutral, or negative. Referring to the Qualitative Summary of both Groups by Category from the Questionnaire links in Appendix -B, the scores indicated that about 66% of the control group and 73% of the treatment group enjoyed the experience of the hands-on performance testing. 73% of the control group assessed their own performance as being negative on the post-test, as compared to only 10% of the treatment group being negative about their post-test performance. When asked how participants felt about how well prepared they were to do the wiring of the post-test, only 49% of the control group felt good, as compared to 72% of the treatment group. Open-ended comments about how the instructional experience could be improved were around 60% neutral for both groups, with about 20% positive, and 20% critical of the training they received.

Summary and Conclusions

Even though the participant groups were small, the Leighton-Graham Method appeared to make the difference in enabling the treatment group to achieve 100% success on the hands-on wiring post-test, as compared to only 45% in the control group, and in 34% less time than the

control group. Based upon the performance data gathered in this Action Research project, the answer to our initial question, "Will guided experiential learning practices in the planning and wiring of electrical circuits impact student hands-on performance skills?" seems to be Yes. While the Leighton-Graham Method of guided hands-on planning and wiring of electrical circuits seems to have made a substantial improvement in the skills of participants in the treatment group, there are probably many ways in which this treatment can be improved. While further study is encouraged, it is safe to say that the actual results of this research astounded us, when compared to our expectations. We believed that our method would be generally effective, but we never imagined that the success rate would be 100% for treatment group participants, where 68% of them had no previous work experience related to the wiring of electrical circuits. This surprised us because nearly half of the control group members had previous work experience related to wiring, yet less than half of them were successful in wiring their circuits properly without receiving the treatment, given three-hours to complete the task.

The second question we asked was, "If so, what will the impacts be?" It is safe to say that the impacts were that improvements were seen in both: (1) student performance; and (2) student satisfaction through use of the guided hands-on, experiential learning provided through use of the Leighton-Graham Method of planning and wiring electrical circuits for the treatment group, as compared to the control group.

Future Actions and Directions

The sample population of our study was very small. So, conclusions based upon these low numbers could be faulty, based upon the logical fallacy of hasty generalizations. Because the best statistical data comes from large sample sizes, this research needs to be repeated and

hopefully correlated to demonstrate even greater relevance and reliability. While the analysis of our data suggests somewhat strongly that teaching students how to plan and wire electrical circuits by the Leighton-Graham Method is an effective process, further research needs to be conducted. Both our Action Research and our teaching methods will be evolving over time. Our desire is to optimize the ways we can accomplish the over-arching goal--preparing teachers to train technicians and future engineers how to more effectively plan and wire electrical circuits, to better serve the needs of industry.

Reflections

We wish to continue to improve and enhance our Leighton-Graham Method of teaching and increase and expand the areas our method can cover, to incorporate more CTE topics. We see that what we have started, can branch out into other areas such as robotics, engineering, fluid power systems, manufacturing and maintenance where there is a high demand for highly trained personnel in our modern workforce. Along the way, we plan to iteratively re-enter the Action Research process, as we strive for continuous improvement, based upon evidence we gather from future studies.

References

Asunda, P. A. (2012). Standards for Technological Literacy and STEM Education Delivery Through Career and Technical Education Programs, *Journal of Technology Education (JTE)(23)2*. https://scholar.lib.vt.edu/ejournals/JTE/v23n2/asunda.html

Burgher, J. K., Finkel, D., Adesope, O. O., & Van Wie, B. J. (2015). Implementation of a Modular Hands-on Learning Pedagogy: Student Attitudes in a Fluid Mechanics and Heat Transfer Course. *Journal of STEM Education: Innovations and Research, 16*(4), 44-54.

Cattaneo, K. H. (2017). Telling Active Learning Pedagogies Apart: From Theory to Practice. *Journal of New Approaches in Educational Research*, *6*(2), 144-152.

Gritzmann, P., Ritter, M., & Zuber, P. (2010). Optimal wire ordering and spacing in low power semiconductor design. *Mathematical Programming*, *121*(2), 201-220.

Herron, S., & Gopal, T. (2012). Pretest/Posttest Plus Prompts: Tools for Research and Evaluation. *Journal of Computers in Mathematics and Science Teaching*, *31*(2), 175-204.

Hightower, D. W., (1974) The interconnection Problem: A Tutorial. *Computer 7(4)* 18-32.

Hunter, W. J. (2015). Teaching for Engagement: Part 3: Designing for Active Learning. *College Quarterly*, *18*(4).

Hyun, J., Ediger, R., & Lee, D. (2017). Students' Satisfaction on Their Learning Process in Active Learning and Traditional Classrooms. *International Journal of Teaching and Learning In Higher Education*, *29*(1), 108-118.

Lawanto, O. & Santoso, H., (2012). Self-Regulated Learning Strategies of Engineering College Students While Learning Electric Circuit Concepts with Enhanced Guided Notes. *International Education Studies* 6(3) 2013 88-104.

Liu, H., & Su, I. (2011). Learning Residential Electrical Wiring through Computer Simulation: The Impact of Computer-Based Learning Environments on Student Achievement and Cognitive Load. *British Journal of Educational Technology*, *42*(4), 598-607.

Pranab, R., Smadrita, B. et al, (2014) A novel wiring planning technique for optimum pin utilization in Digital Microfluidic Biochips. *IEEE Computer Society* for the 27th IEEE Conference on VLSI Design held in Mumbai, India, 510-515.

Safadi, R., & Yerushalmi, E. (2014). Problem Solving vs. Troubleshooting Tasks: The Case of Sixth-Grade Students Studying Simple Electric Circuits. *International Journal of Science And Mathematics Education*, *12*(6), 1341-1366.

Sokoloff, D. R. (2016). Active Learning Strategies for Introductory Light and Optics. *Physics Teacher*, *54*(1), 18-23.

Appendix Table of Content

[These appendices are all located in the attached zipped folder, with the CSUSB 543 submission.]

APPENDIX-A

Literature Review

APPENDIX A

LITERATURE REVIEW--ANNOTATED BIBLIOGRAPHIES

Annotated Bibliography of New Article #1 of 13:

Burgher, J. K., Finkel, D., Adesope, O. O., & Van Wie, B. J. (2015). Implementation of a Modular Hands-on Learning Pedagogy: Student Attitudes in a Fluid Mechanics and Heat Transfer Course. *Journal of STEM Education: Innovations and Research, 16*(4), 44-54.

Regarding the article entitled "Implementation of a Modular Hands-on Learning Pedagogy: Student Attitudes in a Fluid Mechanics and Heat Transfer Course", it was concluded that lecture was a necessary precursor to hands-on us of the Desktop Learning Modules (DLMs). But, after the foundation had been adequately paved, then the DLMs were much more successful than lectures alone. According to Burgher, et al, (2015), "Results indicate that 72% of students receiving the hands-on DLM treatment thought it helped more than lecture; of those receiving lecture, 40% thought that it helped more than the DLM to learn heat transfer concepts. With respect to conceptual understanding, 72% of students agreed they understand and can apply principles related to heat exchangers well, with 28% unsure of their own conceptual understanding".

This article aligns nicely with our procedures, where we continue to use traditional lectures to transmit information to the control group, whereas the treatment group instead receives an initial, short lecture segment, quickly followed by guided hands-on learning experience, using the Leighton-Graham Method of planning and wiring electrical circuits.

Annotated Bibliography of New Article #2 of 13:

Pranab, R., Smadrita, B. et al, (2014) A novel wiring planning technique for optimum pin utilization in Digital Microfluidic Biochips. *IEEE Computer Society* for the 27th IEEE Conference on VLSI Design held in Mumbai, India, 510-515.

The paper from this IEEE Conference on VLSI Design includes major elements of wire planning techniques needed to optimize interconnection wiring in digital electronic circuits. It is similar to the treatment to what we are proposing in our research study. While it is done on a micro-fluidic droplet basis, it can be scaled up to represent out topic, on a larger scale. Double-layer, dual wiring schemes are discussed via algorithms to develop a feasible wiring plan for a given circuit layout, enhance wire routing, and to optimize pin layouts for interconnection.

While much of the article is focused on applications of digital micro-electronics, the universal wire routing and planning can be transferred to the full-scale electrical circuits, such as we are proposing to optimize, using the Leighton-Graham Method of planning and wiring of electrical circuits. The algorithms are virtually the same, and the alternate wiring plans can also be applied to our treatment. This article further adds to the scaffold of supportive information mentioned in the previous Burgher article about the effectiveness of hands-on training experiences.

Annotated Bibliography of New Article #3 of 13:

Hightower, D. W., (1974) The interconnection Problem: A Tutorial. *Computer 7(4)* 18-32.

This IEEE peer-reviewed article, on **The Interconnection Problem**, gives extensive information on interconnection problems and is still relevant today. It covers Pin Assignments, Wire List Determination, Spanning Trees, Layering, Ordering, Rectilinear Steiner Trees, and Wire Layout. We need to cover many of those topics in our guided experiential learning methods of instruction for teaching students how to wire electrical systems. It covers several new ideas that are presented and could provide for better wire layout, including algorithms for better accomplishing wiring tasks, with diagrams and examples. These are well presented and easy to understand. The references also include a large body of supporting information, which is

closely related to our research. But, wiring is usually only taught in university engineering settings. So, it would seem to be badly needed at the community college level, for technicians and maintenance personnel who may never attend an engineering university. This runs parallel to our contention that the teaching of planning and wiring of electrical systems is badly needed, and supports our Leighton-Graham Method, and ties nicely together with the other articles, but from a technological standpoint, rather than merely an educational one.

Annotated Bibliography of New Article #4 of 13:

Hyun, J., Ediger, R., & Lee, D. (2017). Students' Satisfaction on Their Learning Process in Active Learning and Traditional Classrooms. *International Journal of Teaching And Learning In Higher Education*, *29*(1), 108-118.

Active Learning Environments (ALEs) enhance student engagement and more effectively increase student performance than traditional lectures alone. But, changing modern classrooms to fit the needs of an Active Learning Environment is expensive. Education never seems to have a surplus of money with which to enhance programs that are perceived as already being successful. The authors ask what can be done in this regard, considering limited resource availability. The results of their study show that ALEs increase student satisfaction directly, and also serve to boost student learning, productivity, and retention positively.

Student satisfaction was not the goal that drove our use of hands-on guided learning, or the later performance testing in our study. But, it certainly helped the students to stay engaged. While student retention and completion rates are driving forces in most community colleges these days, the lack of hands-on active learning environments is slow to catch on, where traditional lecture-based instruction is still the norm for teaching electrical and electronics theory. It is believed that hands-on learners demand more hands-on activities in programs where

they want to remain loyal. So, the guided learning experiences of the Leighton-Graham Method of planning and wiring electrical circuits both satisfies our CTE hands-on learners, and engages them in their own natural learning styles, which makes the experience even more meaningful and memorable for them.

Annotated Bibliography of New Article #5 of 13:

Hunter, W. J. (2015). Teaching for Engagement: Part 3: Designing for Active Learning. *College Quarterly*, *18*(4).

This is the third part of three related articles about active learning in college. This article was chosen because it focused more on the classroom Active Learning Environment (ALE) than on Constructivism and Teaching Engagement, as did the first two. Here, Hunter outlined the theory behind his rationale an subsequent research, using case-based methods of teaching and problem learning, as he termed it. He went on to described means of facilitating contemporary technologies in traditional classrooms to support ALE. His questions were pragmatic regarding the implementation of ALEs in college courses. However, he left out a lot of the details regarding the transition from lecture-based teaching to ALE learning, especially for teachers who are used to the old ways. Herein, Hunter searched for answers about how to design and implement ALE in traditional classroom spaces.

Active Learning for CTE students means that hands-on activities will be included to both establish and maintain full engagement with these hands-on learners, but also so that true learning may begin through tactile feedback from the objects being manipulated. It is as though the devices are revealing their secrets to the learners via an immersive communications link, akin to telepathy for these learners—that is, experiential learning. Furthermore, the memory of first hand experiences such as these are more lasting and personally internalized by hands-on learners.

Annotated Bibliography of New Article #6 of 13:

Cattaneo, K. H. (2017). Telling Active Learning Pedagogies Apart: From Theory to Practice. *Journal of New Approaches in Educational Research*, *6*(2), 144-152.

Cattaneo said that active learning really starts with foggy definitions that are often confused, intertwined, and contested. His solution was to implement Project-Based Learning (PBL, not to be confused with problem-based learning) by converting theory into practice. He believes that inquiry and discovery are strong tools for learning that are rooted in student projects, where hands-on discovery learning, and experiential learning modalities naturally occur. He classified five ALE pedagogies that are based on six constructivist ideas, related to PBL. By comparative content analysis, the viability of adaption was made to sound very convincing. His goal was learner-centered teaching, using PBL in an ALE. One drawback that Cattaneo mentioned was a dissonance that made it difficult to differentiate the meanings and confused the terms, making it difficult to explain to college STEM program administrators. However problematic that might be, most students enjoyed PBL in the ALE. Students also believed that PBL in ALE would be more transferrable to other classroom and career environments, which spoke well of its acceptance. Employable skills are important to students and the relevance is not lost on them.

Annotated Bibliography of New Article #7 of 13:

Lawanto, O. & Santoso, H., (2012). Self-Regulated Learning Strategies of Engineering College Students While Learning Electric Circuit Concepts with Enhanced Guided Notes. *International Education Studies* 6(3) 2013 88-104.

Peer Review Journal Article

This peer-reviewed article discusses comparisons of traditional lectures with more student interaction during lectures. Researchers were also comparing traditional student note

taking versus the newer enhanced guided notes (EGN) that were generated by the instructor. The students had to complete them during the lecture rather than generate all the notes themselves. This newer concept is part of the Self-Regulated Learning Strategies (SRL), that seem more effective today. Aside from the methods of teaching, and aides to assist the lecturer, there was also much discussion about methods and materials for conveying efficient and effective wiring methods, which is what we are after for our research study. They had 115 students start Fundamental Electronics for Engineers in Fall, 2011. Completing it were 97 students which were 87 males and 10 females. They did learn to interconnect circuits via wiring. Data collection and analysis began by using SRL survey questionnaires. Three exams and the final were also used to measure student performance. The analysis consisted of "descriptive statistics, parametric tests and cluster analysis." Interviews were also conducted, yielding some qualitative results at the end of the term. We can use portions of this study to enhance more effective methods of teaching wiring.

Annotated Bibliography of New Article #8 of 13:

Asunda, P. A. (2012). Standards for Technological Literacy and STEM Education Delivery Through Career and Technical Education Programs, *Journal of Technology Education (JTE) (23)2.*

This article focuses on STEM Literacy as the CTE cornerstone of our modern economy, and the skills needed to keep it growing, which is right on target for our research project. According to Asunda (2012), "Given the pressing needs for a high-quality STEM workforce in 21st century economies, proposals for science, technology, engineering, and mathematics are being developed to meet and create pathways to a wide range of interesting and exciting career opportunities." and, "At a minimum, employers rely on career and technical education (CTE) and workforce training systems to supply workers able to perform in their jobs

(Rojewski, 2002)." This amalgamation of forces seeks to apply STEM-literacy as a force driven by our government to keep our economy growing amid the mass retirements of Baby-Boomers who possess all the skills so desperately needed by our currently unprepared entry-level workers. This includes electrical circuit wiring skills. Even most of the electricians in our control group could not get their circuits wired successfully in a span of three hours, when only 17 wires were needed, according to the schematic diagram they were given. This points to a very real need for the Leighton-Graham Method of planning and wiring electrical circuits.

Annotated Bibliography of New Article #9 of 13:

Safadi, R., & Yerushalmi, E. (2014). Problem Solving vs. Troubleshooting Tasks: The Case of Sixth-Grade Students Studying Simple Electric Circuits. *International Journal of Science And Mathematics Education, 12*(6), 1341-1366.

This article explored the comparison of troubleshooting (TS) and problem-solving (PS) tasks. It also explored the impact on student conceptual understanding. While the study involved two sixth-grade classes with the same teacher, it was adequate for our purposes in the use of the Leighton-Graham Method (LGM), because it was related to the conceptual understanding of electric circuits, related to troubleshooting (TS) and problem solving (PS). For those, it used comparative analysis techniques. The study found student performance on transfer problems was much higher for the TS class, especially for students with less prior knowledge. It described the research questions, the participants, exercises, the statistics, data analysis methods, and conclusion. It used pre-tests and post-tests to capture much of the data, including self-reports. There were many goals and questions being sought in this study, none of which seemed particularly relevant to what we need to know for our study. But, the methods were similar with what we may use to answer parallel questions, with any age-group, regarding basic electrical circuit wiring.

It discussed the concept difficulties in elementary children when it came to simple electric circuits. This points out a need for the LGM to simplify it, so that it does not take an expert to be able to troubleshoot and repair a circuit fault. The implications of this article support the fact that the LGM is needed, and can improve the ability of students, and professionals, for that matter, to troubleshoot wiring errors by following the rules of our technology. While this article discussed troubleshooting and problem solving in a different context than we intend to use, it is still significant that low-levels of understanding are all that are needed to be successful with LGM. Even sixth graders can be taught to be successful in TS and PS.

Annotated Bibliography of New Article #10 of 13:

Sokoloff, D. R. (2016). Active Learning Strategies for Introductory Light and Optics. *Physics Teacher*, *54*(1), 18-23.

In this article, Sokoloff contended that there was an abundance of evidence to support the idea that traditional lecture-base teaching methods were not effective at teaching concepts of the physical sciences. Electricity and Electronics falls into that domain, and so does wiring, for that matter. The major focus of the work in this study was interactive lecture demonstrations, which is how our LGM works, in teaching planning and wiring. But, instead of Interactive Lecture Demonstrations (ILDs), in work-groups, as this article suggests, it would be more desirable to have individuals replicating our behaviors to accomplish the training objectives. However, the use of ILDs in groups is acceptable as part of a holistic plan that includes a mix of both groups and individuals. Sokoloff (2016) enumerated three steps in his process: "(1) use of a learning cycle in which students are challenged to compare predictions--discussed with their peers in small groups--to observations of the physical world; (2) use of guided hands-on work to

construct basic concepts from observations; and (3) use of computer-based tools." We would merge their Real-Time Physics (RTP) Labs with ILDs, and omit his step-1, and focus mainly on step-2, while supporting the use of step-3, in the form of our pre-written Excel spreadsheet templates for Wire-listing and Translation-Matrices, as needed. This would work along with the use of a Computer Aided Design (CAD) program for drawing the node-layout of our method. The key to both this article, and our LGM to teach the planning and wiring of electrical circuits is to stress ILDs of guided hands-on work in the planning and construction of working electrical circuits. Sokoloff contends that there are over 200 physics departments in the U.S. that are using RTP and ILDs to more effectively teach physics students. The same can be done with LGM in planning and wiring.

Annotated Bibliography of New Article #11 of 13:

Liu, H., & Su, I. (2011). Learning Residential Electrical Wiring through Computer Simulation: The Impact of Computer-Based Learning Environments on Student Achievement and Cognitive Load. *British Journal of Educational Technology*, *42*(4), 598-607.

This article indicates that computer simulations are widely used as tools to support science learning, but not for teaching wiring practices. This study focused on computer simulations to teach residential electrical wiring. It was intended to determine if computer simulations taught residential electrical wiring better than traditional Face-to-Face (F2F) classroom environment. It was a quasiexperiment employed with 169 high school students. The treatment group experienced simulations, but the control group had only lectures and demonstrations from their teacher. It also measured cognitive loading on students, which showed that it was elevated by multimedia tasks, as compared to the traditional approach for learning residential wiring. It turned out that statistics demonstrated that the simulation group had better

learning and higher cognitive load and higher efficiency than the control group, as well as scoring higher on achievement tests.

While this study focused on computer simulations, these lessons could also include computer applications to streamline the planning and execution of wiring via Excel and Word charts that could accomplish the same results, using our proposed LGM. Either computer applications, or traditional F2F lectures, could be employed with our materials for teaching wiring. While many of the cited references are old, they still establish the validity of tried and true methods of instruction and materials like those we propose for teaching wire-planning and execution. Other multimedia elements can also be employed to good effect, said the article.

The article also spoke of the small sample size, methodology, assessment instruments, treatment materials, and procedures. The duration of the study was 6 weeks, and 90 minutes per week of training in residential wiring on the computer simulator, or in the traditional F2F classroom environment. T-test data analysis provided statistics by methods indicated in the text. The results indicated no difference in the foundational electricity concepts testing of the treatment group versus the control group. But, there were significant differences in overall achievement on the residential wiring tests. Cognitive loading and instructional efficiency was much higher, and deemed to be beneficial for the simulation treatment group, as opposed to the control group. However, the virtualized environment of simulations may not offer real world choices to students that the traditional F2F environments might, where real components would be used. This is a weakness of this study that may not affect the results of our approach, because our LGM would utilize real electrical components and wiring. At the end of the article, the need for future studies was suggested.

Annotated Bibliography of New Article #12 of 13:

Gritzmann, P., Ritter, M., & Zuber, P. (2010). Optimal wire ordering and spacing in low power semiconductor design. *Mathematical Programming*, *121*(2), 201-220.

In its 21 pages, this article mentions that the key issue for integrated circuit (IC), semiconductors is the low power constraints owing to mandatory heat removal, reliability, and/or battery life specifications. Because power requirements are affected heavily by capacitances between adjacent wiring, optimal spacing and ordering of parallel traces (wires) is vital to the design of low power IC's. Optimal trace spacing represents a convex issue in optimization. Optimal trace ordering is combinatorial and related to the Minimum Hamilton Path issue, natural to IC design constraints. This relates to our LGM for circuit design, documentation, and wiring, and is fundamental to our research. We can use this for documenting optimal wiring, planning for execution of a wire plan, as well as for troubleshooting of an existing circuit that has failed. Our technological solutions can be scaled to work in microelectronics, full-sized electrical distribution rooms within industrial buildings, as well as residential wiring systems. This article begs for its applicability, even on the sub-micron level, in the production of integrated circuits, down to the 70-nanometer-scale. It also mentions the causes of power loss in IC's, and the related capacitive reactance between traces, and switching frequencies that affect it. It discusses optimal wire placement within the IC with formulas to describe optimal wire spacing to reduce inter-electrode capacitance. Minimum Hamilton Path routing and sequencing are described by algorithmic solutions to various configurations.

This paper admits being somewhat derivative, rather than completely original. It defines and describes algorithms for overcoming issues related to wire trace positions, spacing and sequencing. It mentions permutation networks to solve wiring problems in low power semiconductor IC fabrication planning. This will support our contention that the LGM can also

work at the sub-micron level of IC planning and implementation, in addition to its applicability to the Macro-world of electronics and electrician devices, circuits, and application solutions.

Annotated Bibliography of New Article #13 of 13:

Herron, S., & Gopal, T. (2012). Pretest/Posttest Plus Prompts: Tools for Research and Evaluation. *Journal of Computers in Mathematics and Science Teaching*, *31*(2), 175-204.

This research study emphasized the need for biological researchers and educators to learn the new language of biology that embraces computer-based experiments. This study came from a summer series of bioinformatics workshops using biological information computing systems. It used pre-tests and post-tests related to the Human Genome Project and experiential learning and educator reflections. The goal was to ease the transition of educators into the area of computer-based experimentation, so they could have a more positive impact on their own students who would presumably also be involved with these methods and tools of guided inquiry and hands-on, problem-based learning with role-playing to teach bioinformatics. Even the scores of the teachers increased because of this training.

What really caught our attention during this literature review was the high degree of effectiveness cited in the area we also will be using—that is guided, hands-on, experiential learning with the Leighton-Graham Method (LGM) to teach wiring of electrical circuits. This encouraged us even before we began our Action Research project.

APPENDIX-B

Links to Google Assessment Forms

Appendix-B

Those Google Docs Survey Questionnaire Forms can be found at:

https://docs.google.com/forms/d/e/1FAIpQLSfkKMwkjsE6tcx5T4_jxVzwiy2hKMcb4pMhwPyNF1uNGGZ0hA/viewform?usp=sf_link

and at

https://docs.google.com/forms/d/e/1FAIpQLSd0JAcbzfei-I8Nbwud_Q6-U6yA6nDanf3by5-PgwzKFat1UQ/viewform?usp=sf_link

APPENDIX-C

Data Collection forms used

		Start	Time	Time	Time	Time	Time
Performance SHEET		Wiring	Done	Done	Done	Done	Done
STUDENT	#	Time	Wiring 1	Wiring 2	Wiring 3	Wiring 4	Wiring 5
	1	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	2	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	3	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	4	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	5	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	6	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	7	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	8	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	9	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	10	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	11	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	12	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	13	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	14	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	15	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	16	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	17	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	18	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	19	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	20	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	21	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	22	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	23	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	24	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:
	25	H: M:	H: M:	H: M:	H: M:	H: M:	H: M:

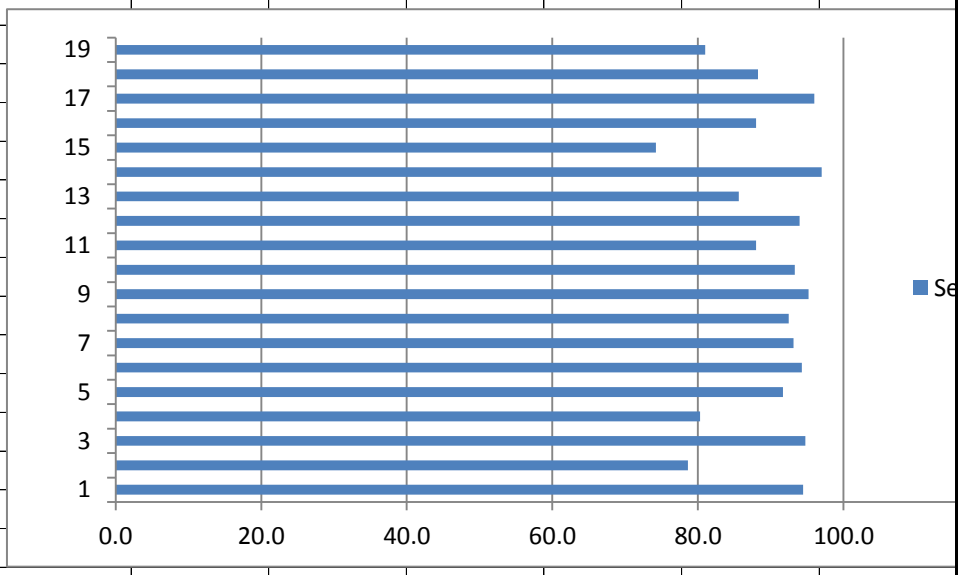
APPENDIX-D

Assessment Results

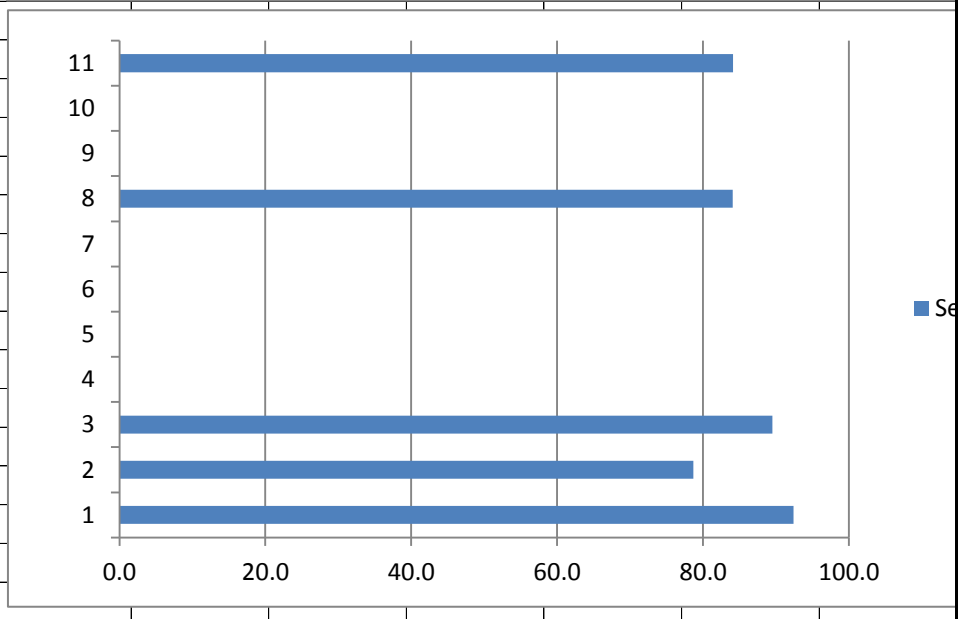
					Elapsed Time of finishing						
Student Group	*Quantitative*				**Wiring Performance Test**						
Treatment #					**Elapsed time**		**Time2Success**				**# of Tests**
1					**72**	1:12:00	**88.9**				1
2					**180**	3:00:00	**72.2**				4
3					**68**	1:08:00	**89.5**				1
5					**126**	2:06:00	**80.6**				5
6					**43**	0:43:00	**93.4**				3
7					**42**	0:42:00	**93.5**				2
8					**89**	1:29:00	**86.3**				1
9					**65**	1:05:00	**90.0**				2
10					**62**	1:02:00	**90.4**				1
11					**87**	1:27:00	**86.6**				1
12					**123**	2:03:00	**81.0**				2
16					**78**	1:18:00	**88.0**				1
17					**154**	2:34:00	**76.2**				2
18					**39**	0:39:00	**94.0**				1
21					**172**	2:52:00	**73.5**				6
22					**91**	1:31:00	**86.0**				3
23					**52**	0:52:00	**92.0**				1
24					**120**	2:00:00	**81.5**				2
25					**149**	2:29:00	**77.0**				4
	Standard Deviation = 6.7%										**Ttmt Group:**
					Elapsed Time of finishing						
Student Group					**Wiring Performance Test**						
Control #					**Elapsed time**		**Time2Success**				**# of Tests**
1					**98**	1:38:00	**84.9**				1
2					**179**	2:59:00	**72.4**				4
5					**71**	1:11:00	**89.0**				3
6			**incomplete**		**overtime > 3Hrs**		**0.0**				6
8			**incomplete**		**overtime > 3Hrs**		**0.0**				5
9			**incomplete**		**overtime > 3Hrs**		**0.0**				1
10			**incomplete**		**overtime > 3Hrs**		**0.0**				3
12					**174**	2:54:00	**73.1**				2
14			**incomplete**		**overtime > 3Hrs**		**0.0**				1
15			**incomplete**		**overtime > 3Hrs**		**0.0**				2
16					**173**	2:52:00	**73.3**				2
	Standard Deviation = 21.9%										**Ctl Group:**
It is assumed that, due to the Doger's World Series game, many students failed to											
come to class this time, which is why participation was so low in the Control Group.											
	LEGEND:		unsuccessful--wired, but never got their circuit working								
			successfully got their circuit working								
	A majority of the students in the Control Group										
	said they worked as Electricians, where proper										
	wiring is critical to safety and reliability.										

Performce Score %	Average Score %
100	94.4
85	78.6
100	94.8
80	80.3
90	91.7
95	94.3
100	93.1
95	92.5
100	95.2
100	93.3
95	88.0
100	94.0
95	85.6
100	97.0
75	74.2
90	88.0
100	96.0
95	88.2
85	81.0
Average =	89.5 %

This top bar-chart represents the scores of all Treatment Group scores, from bottom to top, all successfully completing same circuit wiring test.
This Treatment Group received the special LGM training.

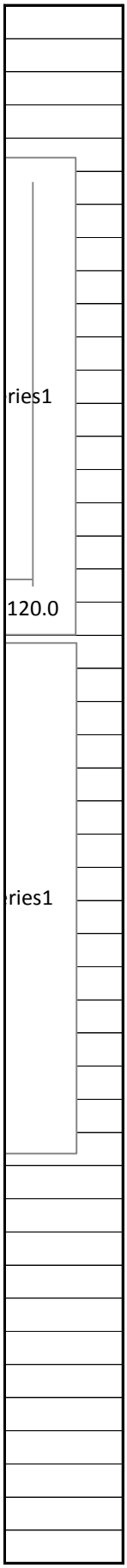


Performce Score %	Average Score %
100	92.4
85	78.7
90	89.5
0	0.0
0	0.0
0	0.0
0	0.0
95	84.1
0	0.0
0	0.0
95	84.2
Average =	39.0 %



This bottom bar-chart represents the scores of all Control Group scores, from bottom to top, five of whom successfully completing the same circuit wiring test.
The six other students failed to get their circuit wired and working in 3 hours time.
All these beginning ELE students received traditional electrical training.

Both the Groups were within 15% of the performance between Pre and Post test results, except that three in the Control Group actually seemed to score much lower on Post test.


ries1
120.0
ries1

Qualitative Summary of both Groups by Category from Questionnaire

Control Group Qualitative Summary, by Category

Q's: 2, 5, 6, 7 & 8 *enjoyment*			Q's:1, 3, 10, 12 & 13 *Instruction*			Q's: 9 & 14 *Comments*			Q: 11 I'm Hands-On			Q: 4 *Self-Performance*					
36	13	6	28	12	15	4	13	5	10	0	1	2	1	8	Q: 19 only *Related Experience*		
(% of 55 total)			13	5	10	(% of 22 total)			(% of 11 total)			(% of 11 total)			5	1	1
65.5	23.6	10.9	41	17	25	18.2	59.1	22.7	90.9	0.0	9.1	18.2	9.1	72.7	(This is Q19… from supplement)		
			(added Q's 15-18 from supplement)												(% of 7 total replies)		
			(% of 83 total)												71.4	14.3	14.3
			49.4	20.5	30.1												

Treatment Group Qualitative Summary, by Category

Q's: 2, 5, 6, 7 & 8 *enjoyment*			Q's:1, 3, 10, 12 & 13 *Instruction*			Q's: 9 & 14 *Comments*			Q: 11 I'm Hands-On			Q: 4 *Self-Performance*					
73	15	12	90	6	6	9	24	7	19	0	1	11	7	2	Q: 19 only *Related Experience*		
(% of 100 total)			46	39	1	(% of 40 total)			(% of 20 total)			(% of 20 total)			6	0	13
73.0	15.0	12.0	136	45	7	22.5	60.0	17.5	95.0	0.0	5.0	55.0	35.0	10.0	(This is Q19… from supplement)		
			(added Q's 15-18 from supplement)												(% of 19 total)		
			(% of 188 total)												31.6	0.0	68.4
			72.3	23.9	3.7												

11 responses

Accepting responses

SUMMARY

1. What are your feelings about the quality and quantity of information you received from your instructor regarding Electrical Circuit Wiring?

11 responses

I received good info

The quality was top notch. Mr. graham knows the subject very well and knows how to show the material to any level of understanding

It was fun and very insightful. I learned a good amount

Good

The information was good

No Complaints, all information received was easy to understand and enough to grasp concepts

Just new to me so i dont get it right away But i will

not enough

I feel both quality and quantity were above average

Good, just a little slower

Its amazing lecture & reading is 2 dimensional, hands on gave me a 3 dimensional aspect and it filled major gaps in my understanding

2. How well did your instructor deliver the material about Electrical Circuit Wiring?11 responses

great

He delivered the material in a manner that simplifies the work

Excellent

Good

He deliver the material on time

very well, examples given were easy to understand and analegies helpful in remembering concepts

Good he explain it the best he could

good, but not to everybody's needs

very well

step by step

Mr. Graham is a very intelligent and knowledgeable instructor, he simplified the subject to be very understandable

3. How did you feel when given the wiring task to complete after your instructor finished the lecture portion of the Electrical Circuit Wiring instruction?11 responses

good
I personally felt I couldn't do it till Mr. Graham explained it in a way we understood. It was then that I looked at it differently, and was almost able to complete it
Excited and felt like getting right to work
not good
I was a little bit confused when he taught, I did the best that I could
It was my responsibility ti fully be able to accomplish what I was tasked to do
Good wish i could get the diagram right
not confident
confident I had the ability to perform the task
Frustrated and uncertain
At first I was lost but that's just me, once I reflected on his teaching, it made sense

4. About how long did it take you to wire your physical components correctly after you started the hands-on performance testing?11 responses

entire class time
The entire class time
the whole class
3 hours
about 3 hours
more than 2 hours
whole class still was not done right
N/A
25 minutes
2 hours 1/2
It took about 1 hr or so, I took my time because I wanted to get it correct

5. What did you enjoy most about the lecture-instruction on Electrical Circuit Wiring?11 responses

hands on (2)
writing was clear -- instruction were clear
I'm not sure
The hands-on portion
some of them. I didn't understand very well
It reinforced the knowledge given/taught from previous lectures
N/A
Transfering theory about wiring / electricity to a circuit that doe ssomething
I like hands on because I start getting visual knowledge
I really enjoyed how Mr. Graham breaks down each chapter and makes the subject matter very interesting

6. What did you enjoy most about the hands-on performance testing regarding Electrical Circuit Wiring?11 responses

hands-on!
Learning from my mistakes and being explained on why the way I wired the circuit did not work
learning how to wire with actual materials
The outcome of my wiring
testing is the best part
To be able to see if I am capable of finishing an actual project by myself
trying to make it work
being hands on
making it work as intended
It works best for me
It was fun over all, but any hands on really gives as I said a 3D perspective and understanding

7 What did you enjoy least about the lecture section regarding Electrical Circuit Wiring?11 responses

N/A (2)
The problems at the end of each section. I believe I would have understood the material more if we got more in-depth
I didn't have enough hands-on experience to complete circuit
Patience
wiring the wires on the relays and switchs
Nothing I did not enjoy
How i didnt get it to work
?
Not knowing the locations
I didn't have any negative thought as to the lecture aspect, but I have always felt this is a course that needs more hands on

8. What did you enjoy least about the hands-on performance testing regarding Electrical Circuit Wiring?11 responses

messing up, getting frustrated
Nothing, i enjoyed it very much. I learned more than the lecture
I just wish I had more time to finish me circuit prorperly
Nothing
I enjoyed wiring a little bit
Nothing I did not enjoy
How i didnt get it to work
N/A
Broken light bulb in test tower light
Nothing -- I like it
Nothing, I love it

9. Please list any ideas you have about how this electrical wiring instructional experience could be improved.11 responses

N/A (4)

N/A It was great

I think if we went over the problems in each chapter we would get a better understanding

I feel that if we got more hands-on work. the hands on portion would come easier

more labs

I think this experience tests 100% of information taught

Study, study, study

Needs a lab portion to it

10. I was totally confused about how to wire the physical components from the schematic diagram.11 responses

1234501233 (27.3%)1 (9.1%)2 (18.2%)3 (27.3%)2 (18.2%)

Value	Count
1	3
2	1
3	2
4	3
5	2

11. I am a hands-on learner, in that I like touching and manipulating the physical items about which I am taught.11 responses

1234502468101 (9.1%)0 (0%)0 (0%)0 (0%)0 (0%)1 (9.1%)9 (81.8%)

Value	Count
1	1
2	0
3	0
4	1
5	9

12. The teacher fully prepared me to succeed on my hands-on wiring performance test.11 responses

12345024680 (0%)0 (0%)0 (0%)0 (0%)4 (36.4%)0 (0%)0 (0%)7 (63.6%)

Value	Count
1	0
2	0
3	4
4	0
5	7

13. I really understood how to wire the electrical circuit in the hands-on performance test.11 responses

1234501232 (18.2%)2 (18.2%)2 (18.2%)2 (18.2%)3 (27.3%)

Value	Count
1	2
2	2
3	2
4	2
5	3

14. Please enter any additional comments you might have regarding the training in electrical circuit wiring.11 responses

N/A (6)

I enjoyed the hands on portion of our class. I just feel that with more practice and study I would of known more.

good training

Any errors caused from my carelessness in wiring. Something as careless as placing wires into N.C. position instead of N. O. position should not happen

keep at it, don't give up

Just more hands on!

Group-C Supplement

15 – What are your feelings about the quality and quantity of information your received to prepare you for electrical circuit wiring?7

responses

The quality of the information was good.
The Quality is well. So, given there is so much to take in. I personally feel as though I need more time, but can't speak for others.
We only had one wiring project before the lelcctvical circuit. So I feel we dint receive much information.
need more handson and explanation because after a while you forget
Quality and quantity were more than enough to prepare for electrical circuit wiring. Teaching us how to write node lists helped make the wiring much much easier. All errors come from carelessness and inexperience.
I feel like I get it a little bit, but need ask more questions.
A lot of information at a very rapid pace, and its quality information, but if you don't know what it means, or how it work, it does not profit them.

16 – How well did this information prepare you to do the electrical circuit wiring?7 responses

The information prepared me well for the electrical wiring
I did not understand the diagram, so it took me quite a while. Other students finished quite quickly.
the information we did receive, was helpful
good on the first project but by the second project it had been a while and I forgot how to do it
More than enough. We really only needed how to write node list to make everything easier; however, it was not needed. The schematic was pretty straight forward.
I know more now than when I started the class.
not very well, the hands-on lab classes were more beneficial to me.

17 – How well did this instructional information cover methods of circuit wiring?7 responses

He covered all the methods of circuit wiring clearly
Quite well. As many students nearly completed the project.
it was brief
OK
Unsure what is meant by "method of circuit wiring". If this is regarding the circuit before the wiring test, it was more than enough. All we need is to be able to see where one point goes to.
very good
It covered them, but again the pace was way too fast.

18 – Did you know any methods planning and circuit wiring that you did not use? If so, what were they and why did you choose not to use them this time?7 responses

no (2)
I used all the methods as the instructor explained.

yes, the node list. we did not receive how to node-list.

none

No, I did not have any method. Everything I used was off what professor graham taught.

unknown?

19 – Have you ever worked in a job that required electrical wiring, electrical maintenance, or troubleshooting of electrical wiring? If so, please describe it here.7 responses

Yes at my job I have been doing small electrical maintenance and troubleshooting. Still have a lot to learn.

Yes, I worked as an electrician for almost a year, troubleshooting plugs, switches, lights, etc., wiring homes and new circuits. Installing recessed light. Chandelier pendant, etc.

no.

yes trouble shooting a circuit e.g.lights

No, this is my first electrical course.

yes, low voltage

as a computer tech, when I got certified by Microsoft (1996), not too much wiring

Group-C

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9. Please list any ideas you have about how this electrical wiring instructional experience could be improved.11 responses

N/A (4)
N/A It was great
I think if we went over the problems in each chapter we would get a better understanding
I feel that if we got more hands-on work. the hands on portion would come easier
more labs
I think this experience tests 100% of information taught
Study, study, study
Needs a lab portion to it

10. I was totally confused about how to wire the physical components from the schematic diagram.11 responses

1234501233 (27.3%)1 (9.1%)2 (18.2%)3 (27.3%)2 (18.2%)

Value Count

Value	Count
1	3
2	1
3	2
4	3
5	2

11. I am a hands-on learner, in that I like touching and manipulating the physical items about which I am taught.11 responses

1234502468101 (9.1%)0 (0%)0 (0%)0 (0%)0 (0%)1 (9.1%)9 (81.8%)

Value	Count
1	1
2	0
3	0
4	1
5	9

12. The teacher fully prepared me to succeed on my hands-on wiring performance test.11 responses

12345024680 (0%)0 (0%)0 (0%)0 (0%)4 (36.4%)0 (0%)0 (0%)7 (63.6%)

Value	Count
1	0
2	0
3	4
4	0
5	7

13. I really understood how to wire the electrical circuit in the hands-on performance test.11 responses

1234501232 (18.2%)2 (18.2%)2 (18.2%)2 (18.2%)3 (27.3%)

Value	Count
1	2
2	2
3	2
4	2
5	3

14. Please enter any additional comments you might have regarding the training in electrical circuit wiring.11 responses

N/A (6)

I enjoyed the hands on portion of our class. I just feel that with more practice and study I would of known more.

good training

Any errors caused from my carelessness in wiring. Something as careless as placing wires into N.C. position instead of N. O. position should not happen

keep at it, don't give up

Just more hands on!

Group-T Supplement

15 – What are your feelings about the quality and quantity of information you received to prepare you for electrical circuit wiring?19 responses

I feel that the quality and quantity of information I have received for the electrical circuit wiring is enough to get me started

My feeling are that I feel good about the quality and quantity of information I received to prepare me.

I feel I'm learning and receiving all the right information to prepare me for electrical circuit wiring

I feel that it was the best explanation could've helped us. It was a good refresher on what we've been taught here.

Information was well prepared.

I felt confident that the information was sufficient to prepare me for electrical circuit wiring

Very good, so far all the information received has been amazing and has been really helpful.

The quality was excellent, the quantity was sufficient.

The quality is really good. I hope we can go over it a couple of more times, so everyone is on the same page.

I felt 100% prepared! If I had any problems (which I did) it would have been my own fault, or I equipment was faulty.

I think Im getting enough information that is getting me prepared for the electrical wiring.

I like it both the quality and quantity.

The quality of information that covered electrical circuit wiring was excellent it was thoroughly explained with made it easy to understand, a lot of information was covered and made it easy to understand.

Its bin great. All the things ive been taught I use

The quality and quantity I've received is ample amount of information, I have a good feeling about this class.

I feel the quality of the information is top notch. The information is not overwhelming and the amount of information we've been given is distributed at at sustainable pace.

I am now learning and I feel I received enough quality instruction to keep up with the proffesor and students.

There is a lot of good information, sometimes the class moves a little too fast.

I was really satisfied. What was offered put us on the track.

16 – How well did this information prepare you to do the electrical circuit wiring?19 responses

Very well (2)

It prepared me very well

It prepared me really well to do the electrical circuit wiring

It prepared me to do every correctly

It allowed me to get started easily and in a more organized manner.

I did well.

A lot by showing me how nodes work and how all wiring is done.

The information is great, I just wish we could have a couple of more examples

I was very well prepared

Pretty good, I learned new easy method how to wire

Very much. When troubleshooting, doing this methodology really comes in handy. I can almost find the problem right away.
I was very prepared when I was tasked to perform the electrical circuit wiring.
Extremely well. He prepared me for everything.
The information prepared me very well.
I feel that I am prepared to instruct myself and others on how to wire.
I have completed my tasks and have been able to correct problems when I did not correctly wire a project correct the first time.
The hands-on is very helpful
Very well. I have confidence now to do electrical wiring jobs.

17 – How well did this instructional information cover methods of circuit wiring?19 responses

The information covered the methods all clearly
It has helped to choose different methods to do the circuit wiring
I feel like I'm ready to start working
Really well. We were given a circuit diagram that showed the connections.
Covered all basis.
I donot know how many methods there are, so I can't answer the question.
Very well, so far this class gives a ton of details and information.
It covered the Leighton-Graham method well, but did not cover any other methods
The instructions are good and cover How to Build, and Troubleshoot, but if you miss one part, you are totally lost.
It covered all methods of a wiring circuit
Pretty good
It was fantastic. Mr. Graham is a great professor and knows how to explain thing thoroughly.
The instructional information covered the methods of circuit wiring very well. I have learned methods that I am now using at my current job.
Covered everyhting Ive been shown.
It covered everything we had to know about circuit wiring so far.
Very well, I think he was very thorough.
I covered various methods and practiced to identify the advantages and disadvantages to each.
Very well.
It was covered properly.

18 – Did you know any methods planning and circuit wiring that you did not use? If so, what were they and why did you choose not to use them this time?19 responses

No (3)
N/A (2)
no--I used them all
I didnot know any methods planning and circuit wiring
No--I used every method that was taught in class
No. I chose to use all the methods I was taught.
Not that I know of.
I did not use point to point, I wanted to practice terminal block wiring
Yes. Instead of doing nice borad wring, I just did point to point wiring.

This is all totally new to me.

I rats-nest wiring, but didnt use the method because it was more messy

I used everything that Mr. Graham taught us.

No, i did not have any prior methods for planning circuit wiring before this course.

No I don't

Everything I am learning is my first time coming across these techniques.

No methods known.

19 – Have you ever worked in a job that required electrical wiring, electrical maintenance, or troubleshooting of electrical wiring? If so, please describe it here. 19 responses

N/A (3)

No (3)

I have never worked in such a job

No, I have not

No.

First time wiring anything.

Installed, replaced, repaired new and existing residential wiring.

I have not done such just yet.

Yes, wire harness building at SpaceX, splicing and building to connectors

Yes, one time I had to troubleshoot a circuit that had a short but fand out that a wire wasnt making connections

No, I havn't.

Yes, I am currently working at a distribution center. I troubleshoot equipment used in a production line. I work on wiring electrical panels and circuits. Troubleshooting VFDs, contactors, motors and other electrical controls.

Yes, I used to renovate homes. So sometimes I had to change the sockets and test the wiring to make sure they were still good.

None

Yes. I was in a perfume factory, with so many machines for mixing and filling. Diagnosing the electrical wiring was really challenging, but not anymore.

15. What are your feelings about the quality and quantity of information your received to prepare you for elect
The quality of the information was good.
The Quality is well. So, given there is so much to take in. I personally feel as though I need more time, but can't s
We only had one wiring project before the lelcctvical circuit. So I feel we dint receive much information.
need more handson and explanation because after a while you forget
Quality and quantity were more than enough to prepare for electrical circuit wiring. Teaching us how to write noc
I feel like I get it a little bit, but need ask more questions.
A lot of information at a very rapid pace, and its quality information, but if you don't know what it means, or how

3 are Positive
1 is Neutral
3 seem Negative, or critical

Control Group Supplemental Questions Responses

16. How well did this information prepare you to do the electrical circuit wiring?

The information prepared me well for the electrical wiring
I did not understand the diagram, so it took me quite a while. Other students finished quite quickly.
the information we did receive, was helpful
good on the first project but by the second project it had been a while and I forgot how to do it
More than enough. We really only needed how to write node list to make everything easier; however, it was not
I know more now than when I started the class.
not very well, the hands-on lab classes were more beneficial to me.

4 sound Positive
0 sound Neutral
3 sound Negative

17. How well did this instructional information cover methods of circuit wiring?

He covered all the methods of circuit wiring clearly
Quite well. As many students nearly completed the project.
it was brief
OK
Unsure what is meant by "method of circuit wiring". If this is regarding the circuit before the wiring test, it was m
very good
It covered them, but again the pace was way too fast.

3 seem Positive
3 seem Neutral
1 seems Negative, or critical

18. Did you know any methods planning and circuit wiring that you did not use? If so, what were they and why
I used all the methods as the instructor explained.
no
yes, the node list. we did not receive how to node-list.
none
No, I did not have any method. Everything I used was off what professor graham taught.
no
unknown?

3 seem Positive
1 seems Neutral
3 seem Negative, or critical

19. Have you ever worked in a job that required electrical wiring, electrical maintenance, or troubleshooting of
Yes at my job I have been doing small electrical maintenance and troubleshooting. Still have a lot to learn.
Yes, I worked as an electrician for almost a year, troubleshooting plugs, switches, lights, etc., wiring homes and ne
no.
yes trouble shooting a circuit e.g.lights
No, this is my first electrical course.
yes, low voltage
as a computer tech, when I got certified by Microsoft (1996), not too much wiring

5 sound Positive to ELE Work Experience
1 was Neutral to having had ELE Work Experience
1 was Negative to having had ELE Work Experience

electrical wiring? If so, please describe **Control Group Supplemental Questions Responses**

w (**15. What are your feelings about the quality and quantity of information your received to prepare you for e**

3 are Positive
1 is Neutral
3 seem Negative, or critical

feelings about the quality and quantity of info

16. How well did this information prepare you to do the electrical circuit wiring?

4 sound Positive
0 sound Neutral
3 sound Negative

information prepare you

17. How well did this instructional information cover methods of circuit wiring?

3 seem Positive
3 seem Neutral
1 seems Negative, or critical

instructional information coverage

18. Did you know any methods planning and circuit wiring that you did not use? If so, what were they and v

3 seem Positive
1 seems Neutral
3 seem Negative, or critical

methods planning and circuit wiring

STTLs =

19. Have you ever worked in a job that required electrical wiring, electrical maintenance, or troubleshooting

5 sound Positive to ELE Work Experience
1 was Neutral to having had ELE Work Experience
1 was Negative to having had ELE Work Experience

Prior or current related work experi

lectrical circuit wiring?

3	1	3
4	0	3
3	3	1

***w*hy did you choose not to use them this time?**

3	1	3
13	**5**	**10**

ɜ of electrical wiring? If so, please describe it here.

ence

APPENDIX-E

General Handouts

Datasheet for 543csu, describing the proper operation of the circuit known as the AHOT project

Description of the proper operation of the AHOT project circuit after wiring is complete:

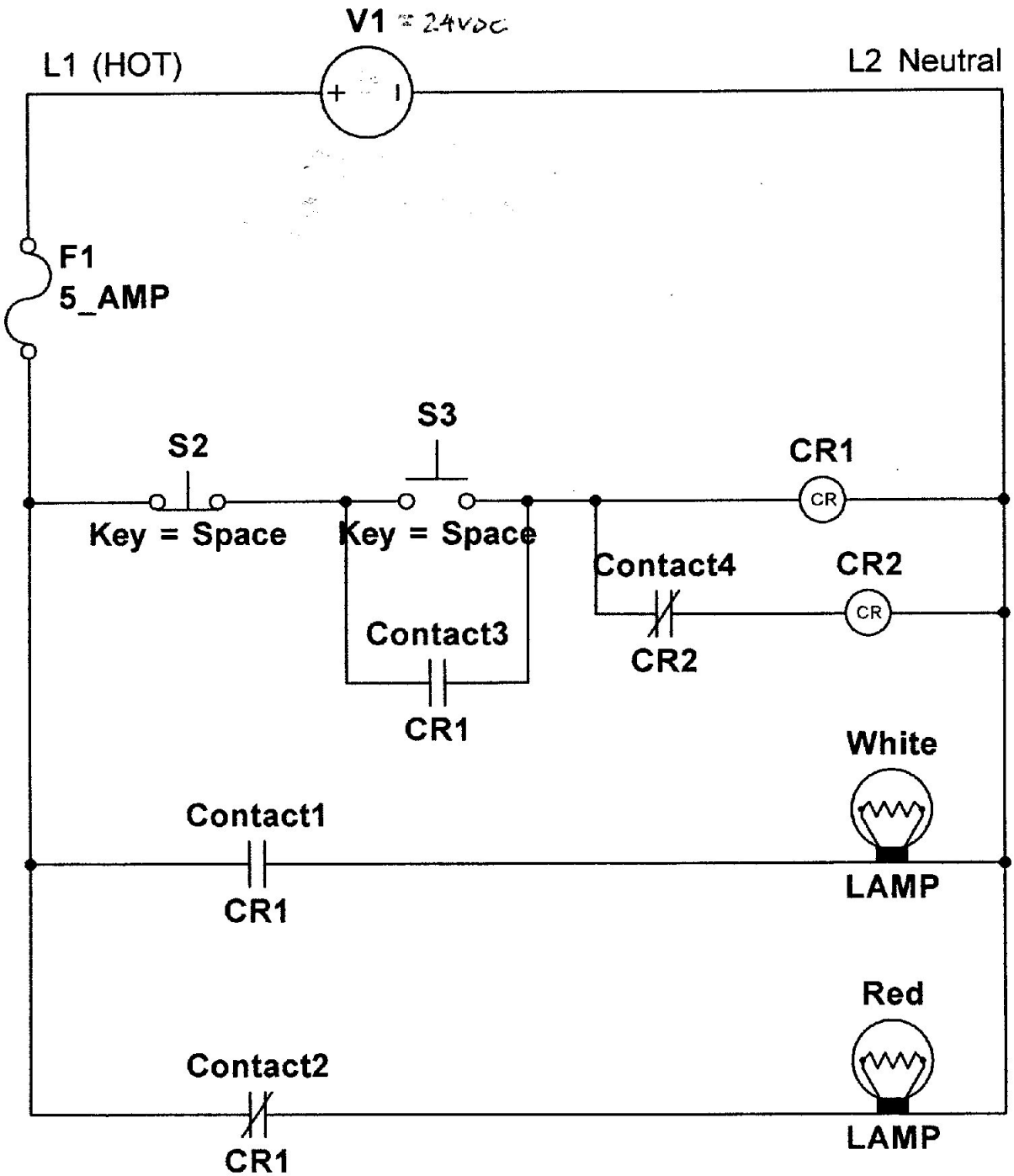
TESTING THE STIMULI AND RESPONSES OF THE MANUAL START/STOP PUSH-BUTTON SWITCHES:

(1) Connect power sources to the circuit you just wired;
(2) Turn on the power sources;
(3) To test the manual start/stop push-button switch-combination (red and green switches, built into the same housing)--first, push the green start-push-button;
(4) When you first push the green start push-button, relay CR1 should click once as it latches on, and make no sound when you release that green start push-button;
(5) Next, press the red stop push-button switch, and watch both CR1 and CR2 relays click once as you press it in. The CR1 relay should unlatch, as the CR2 relay activates;
(6) Then, you should hear only a single click from relay CR2 dropping out, as you release the red stop push-button switch. This will complete the test of the manual start/stop operation. If it behaved exactly as described above, then you have successfully wired the manual switching to the AHOT relay control circuit; and you can move on to test the automatic operation of the limit switches, LS1 and LS2, in step-7, below.

TESTING THE STIMULUI AND RESPONSES OF THE AUTOMATED LIMITS SWITCHES, LS1 and LS2:

(7) After having just completed step-6, above, with relay CR1 still unlatched, press the lever of the LS1 limit switch (a micro-switch), and observe a single click of CR1 as it latches on again; and notice that there is no second click as you release the LS1 limits switch;
(8) Next, press the lever of the LS2 limit switch and notice that relay CR1 clicks as it unlatches, nearly simultaneously with a single click of relay CR2, as it activates; and, notice that there is also a second click of CR2 as the lever of LS2 is released.
(9) If these actions occurred exactly as described, please call your instructor, or test proctor, to come and repeat these tests. Your assessment results will be logged in the gradebook after the verification is complete.
(10) If proper operation of your circuit was not verified, then you must go back and troubleshoot circuit wiring errors before returning to repeat these two testing phases. You have the balance of your 2 ½ hours of planning, wiring, and testing time to finish all necessary work to make your wiring perfect, and pass both of these tests, with instructor/proctor verification.

Lab Challenge #3



Scoring RUBRIC for 543csu AHOT planning, wiring, and testing performance assessment:

Any error in planning the wire-listing, error in wiring any wire from source to destination, or any fault in testing will lose 5% of 100% possible points. Even if the final circuit does not work properly, a student may still earn points. But, a non-functional circuit will have either planning or wiring errors, or both, which will reduce the total points earned.

Performance Test grade outcomes will correlate with percentage scores earned, as follows:

A = 90 to 100%

B = 80 up to, but not including 90%

C = 70 up to, but not including 80%

D = 60 up to, but no including 70%

F = below 60% (usually, only if the circuit wiring is never correct; and then = 0, after 3 hours)

APPENDIX-F

Leighton-Graham Method Handouts

Circuit _____				WIRE List, Pg-1 (landscape/wide)	Name			TL	TC	TR
# of	Clr	COLOR (clr)	NODE	PRINT CLEARLY **in PENCIL,** use commas between con	CON	LOCATION		ML	MC	MR
Wires		NAME	#	CONSTITUENTS (CON) add side indicators	{ # }	on schematic		BL	BC	BR
swatches				examples: R1-A, C3+, D2-K Red; (use commas between & ; at end)						
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					

Circuit _____				**Wire List, Pg-2 (landscape/wide)**	Name			TL	TC	TR
# of	Clr	COLOR (clr)	NODE	PRINT CLEARLY **in PENCIL,** use commas between con	CON	LOCATION		ML	MC	MR
Wires		NAME	#	CONSTITUENTS (CON) add side indicators	{ # }	on schematic		BL	BC	BR
swatches				examples: R1-A, C3+, D2-K Red; (use commas between & ; at end)						
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
					{ }					
							.			

Node I.D.-Tag:		**Translation Matrix: from Wiring I.D. Tag to Terminal Description** (like: 1A is = +24VDC)
"Number/Letter-		**Title of Project:** page # _____ of _____ pages; **Student Name**_____
pair", i.e.: "1A"		**Node Group-Member Terminal, Wire Description**, pin number, etc. (example: S2-A, CR2-p3, +24VDC)
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	
	is =	

APPENDIX-G

Leighton-Graham Method Answer Keys

Circuit ___		PERFORM TEST		WIRE (Node) List, Pg-1 (landscape/wide)	Name=		Location:		
Version 2b		COLOR (clr)	NODE	PRINT CLEARLY **in PENCIL,** use commas between			TL	TC	TR
	Clr	NAME	Wire#	Node-Group Member, with device & terminal indicators			ML	MC	MR
Copyright 2017, NPD Corp.				examples: R1-A, C3+, D2-K Red			BL	BC	BR
Delimiters: 1) colon begins node definition; 2) dash within a name; 3) commas between terminals; 4) semicolon=more nodes follow; 5) period=DONE.									
[#wires]	swatches				{#trmls}				
[1]		RED	1	V1+, F1-A;	{ 2 }	T L			
[3]		BROWN	2	F1-B, S2-A, CR1-p8, CR1-p3;	{ 4 }	M B L			
[2]		Light Blue	3	S2-B, S3-A, CR1-p7;	{ 3 }	M C			
[3]		ORANGE	4	S3-3, CR1-p4, CR1-B, CR2-p3;	{ 4 }	M C			
[1]		DARK BLUE	5	CR2-p9, CR2-B;	{ 2 }	M C			
[1]		VIOLET	6	CR!-p5, White Lamp-A;	{ 2 }	M B			
[1]		PINK	7	CR1-p9, Red Lamp-A;	{ 2 }	M B			
[4]		GREEN	8	V1 -, CR1-A, CR2-A, White Lamp-B, Red Lamp-B.	{ 5 }	T M B L			
[ ]					{ }				
[ ]					{ }				
[ ]					{ }				
[ ]					{ }				
[ ]					{ }				
[#wires]					{#trmls}				

Circuit ________________				WIRE (Node) List, Pg-2 (landscape/wide)	Name=		Location:		
Version 2b		COLOR (clr)	NODE	PRINT CLEARLY **in PENCIL,** use commas between			TL	TC	TR
	Clr	NAME	Wire#	Node-Group Member, with device & terminal indicators			ML	MC	MR
Copyright 2017, NPD Corp.				examples: R1-A, C3+, D2-K Red			BL	BC	BR
Delimiters: 1) colon begins node definition; 2) dash within a name; 3) commas between terminals; 4) semicolon=more nodes follow; 5) period=DONE.									
[#wires]	swatches				{#trmls}				
[ ]					{ }				
[ ]					{ }				
[ ]					{ }				
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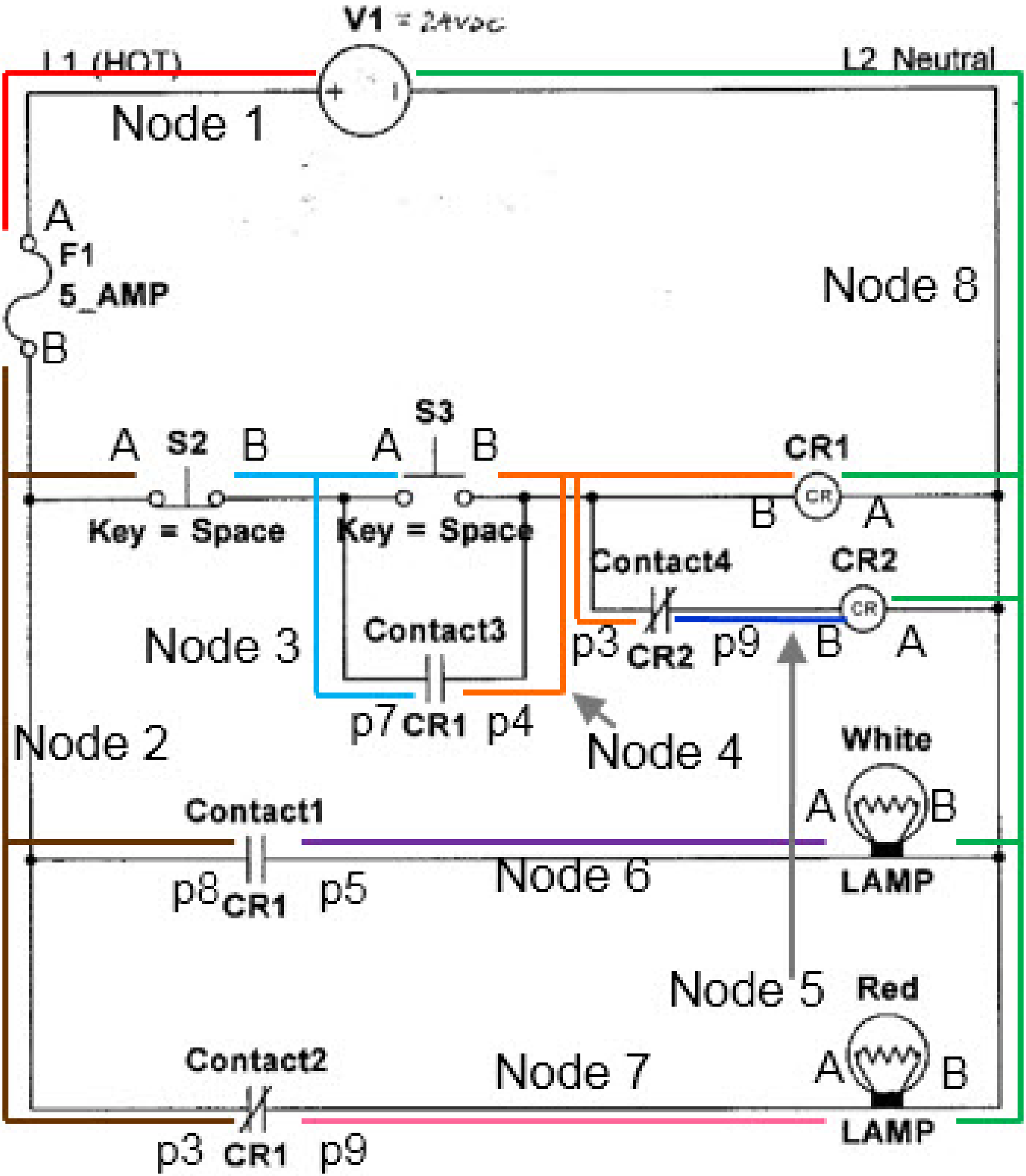
[ ]					{ }				
[ ]					{ }				
[ ]					{ }				
[#wires]					{#trmls}		.		

Node I.D.-Tag:	(V2b)	**Translation Matrix: from Wiring I.D. Tags to Device Terminal Descriptions** (like: 1A is = +24VDC)
"Number/Letter-		**Title of Project: 543 Lab Challenge #3** page # 1 of 2 pages; **Student Name:** _____
pair", i.e.: "5C"		**Node Group-Member Terminal, Wire Description** (device-pin#, etc.--ie: S2-A, CR2-p3, +24VDC) **Copyright 2017, NPD Corp.**
1A	is =	RED, Power-Supply Positve (+24VDC)
1B	is =	F1, Line-side of fuse-holder
	is =	
2A	is =	F1, Load-side of fuse-holder
2B	is =	S2-A, Line side of Red N.C. Stop Switch
2C	is =	N.O. Contact on CR1-Pin 8
2D	is =	N.C. Contact on CR1-Pin 3
	is =	
3A	is =	S2-B, Load-side of Red N.C. Stop Switch
3B	is =	S3-A, Line-side of Green N.O. Start Switch
3C	is =	N.O. Contact on CR1-Pin 7
	is =	
4A	is =	S3-B Load-side of Green N.O. Start Switch
4B	is =	N.O. Contact on CR1-Pin 4
4C	is =	Coil on CR1-Pin B (Left --> Line side of this coil)
4D	is =	N.C. Contact on CR2-Pin 3
	is =	
	is =	continued on page 2

Node I.D.-Tag:	(V2b)	**Translation Matrix: from Wiring I.D. Tags to Device Terminal Descriptions** (like: 1A is = +24VDC)
"Number/Letter-		**Title of Project:__543_Lab Challenge #3_P**age # __2__ of __2__ pages; **Student Name:**_____
pair", i.e.: "5C"		**Node Group-Member Terminal, Wire Description** (device-pin#, etc.--ie: S2-A, CR2-p3, +24VDC) **Copyright 2017, NPD Corp.**
5A	is =	N.C. Contact on CR2-Pin 9
5B	is =	Coil on CR2- Pin B (Left --> line side of this load
	is =	
6A	is =	N. O. Contact on CR1-Pin 5
6B	is =	Lamp, White, Line-side-A of this load
	is =	
7A	is =	N. C. Contact on CR1-Pin 9
7B	is =	Lamp, Red, Line-side-A of this load
	is =	
8A	is =	Black, Power-Supply negative (24VDC)
8B	is =	Coil on CR1- Pin A (Right --> Line side of this load
8C	is =	Coil on CR2-Pin A (Right --> Line side of this load)
8D	is =	Lamp, White, Pin-B (Return side of this load)
8E	is =	Lamp, Red, Pin-B (Return side of this load)
	is =	
	is =	
	is =	


V1 = 24vdc
L1 (HOT)
L2 Neutral
Node 1
A
F1
5_AMP
B
Node 8
S3
A S2 B
A B
CR1
Key = Space
Key = Space
B CR A
Contact4
CR2
Node 3
Contact3
p3 CR2 p9
B A
p7 CR1 p4
Node 2
Node 4
White
Contact1
A B
p8 CR1 p5
Node 6
LAMP
Node 5
Red
Contact2
Node 7
A B
LAMP
p3 CR1 p9

CITI PROGRAM

Completion Date 09-Nov-2017
Expiration Date 08-Nov-2020
Record ID 25034700

This is to certify that:

Glen Graham

Has completed the following CITI Program course:

Human Research (Curriculum Group)
Social Behavioral Research Investigators and Key Personnel (Course Learner Group)
1 - Basic Course (Stage)

Under requirements set by:

California State University, San Bernardino

CITI
Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w44140b5a-99df-4cf7-bf3b-4e9b8baab8b0-25034700

NORCO COLLEGE

2001 Third Street, Norco CA 92860 - 951-372-7000

INFORMED CONSENT FORM

Principal Investigator (PI): Teacher, Glen Graham
Phone: 951-372-7166
Project Title: E543 Wiring Training Research for Fall 2017

You are invited to participate with no obligation in a research study which has as its main purpose to measure student performance at Wiring a given Electrical circuit, in both a Pre-test and Post-test formats. Working with California State University, San Bernardino, it is our intention to develop and validate a new type of wiring instruction program that will help students to become more proficient in the planning and wiring of Electrical circuits.

If you choose to participate in this research study, you should know that the risks are minimal--the circuit runs on a safe, 18 to 24 volts only. The study duration is only one day; and, all data will be anonymously recorded, for both students and for your specific course at Norco College. The study results will only be reported to the ETEC543 course instructor and graduate students, and may also be posted on the CSUSB Blackboard for their use, for which a password will be required for accessing the data and results. The research study results will not be available to the general public. At no point, will your identity be revealed--an arbitrary one-up, two-digit number will be substituted for your name at the time data is recorded; and, your name will not be attached to any of the records. You will also be asked to complete a survey at the end of the study, to which you can record your perceptions of the experience, on a short, 14-item questionnaire.

Whether or not you choose to participate will not interfere with your course-grade, or current, or future relationship with your teacher. You may withdraw from participating in the study at any time, without a penalty.

If you have any questions now, please ask teacher now. Do you have any questions? Circle: **Yes** or **No**

This study will happen in your current classroom, as soon as you have consented to participate. You will have the entire regular class time to perform the pre-test and post-test--both in the form of the wiring an Electrical circuit, to be done individually--not in a team. So, you must work alone at all times, not consulting anyone other than the teacher for additional information.

By signing, below, you are deciding if you will freely participate in this research study, or not, and to allow the Principal Investigator (your teacher) to use the results of these wiring performance tests for research and presentation purposes only. Your signature also affirms that you are 18 years of age, or older.

All students need to sign this paper, whether they participate in the study or not, thank you.

I agree to participate. or I choose NOT to participate. (circle one of these choices)

Student Signature _____Date signed _____

Please Print Name Clearly _____Class _____