Session: FB1-2

CHALLENGE-BASED INSTRUCTION IN ELECTRONICS AND MECHATRONICS

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Abstract

Several challenges have been developed and implemented in the Department of Mechanical Engineering at the University of Texas-Pan American (UTPA) in collaboration with South Texas College (STC) for instruction in basic Electronics and Mechatronics topics. Some of these challenges were implemented in a new Introduction to Science, Technology, Engineering, and Mathematics (Introduction to STEM) course during the summer II term, in 2009, at two campuses in South Texas College (STC). Other challenges were implemented in the Introduction to Mechatronics elective course in the Department of Mechanical Engineering at UTPA, during the 2009 fall semester. This paper presents a description of the challenge-based approach that was followed and it describes the steps and activities that were implemented for a specific challenge that targets concepts in basic Electronics. In addition, assessment results of pre-test, post-test, and affect survey are also presented in this paper. Examples of the materials used for the challenges and assessment tools developed to determine the students' understanding of the topics studied in the challenge are also included. Hands-on activities were important components of each challenge and they are described in this paper. This work has been developed as part of a College Cost Reduction Access Act (CCRAA) grant from the US Department of Education to UTPA in collaboration with STC.

1. Introduction

A project to strengthen and support STEM pathways at the University of Texas-Pan American (UTPA) and South Texas College (STC) has been developing with the support of a College Cost Reduction Access Act (CCRAA) grant from the US Department of Education. As part of this project, challenge-based instruction (CBI) with hands-on activities have been implemented in two particular courses in which basic Electronics and Mechatronics topics are studied. One of the main goals of implementing CBI is to encourage students to understand and integrate multidisciplinary concepts through modern instruction methods and experimentation. To successfully implement CBI, several fundamental requirements must be met to ensure that challenges are educationally effective and that students develop adaptive expertise to apply concepts in multiple contexts. CBI is approached by following the Star Legacy Cycle [17] which provides an appropriate structure and procedure for implementation. There could be great variety

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of challenges and some extend beyond the classroom, requiring several stages and days of work until the instructor deems that the allotted time has been sufficient to complete the assignment. In this study, four continuous hours were dedicated to a specific challenge. However, challenges were given to the students at the beginning of one-hour classroom session, followed by approximately two and a half hour hands-on activity, and finally, a half an hour wrapping up session. To implement CBI, numerous questions might arise about group size, students willing to work together, individualized grading procedures, and how to measure student success in collaborative learning environments. Laporte [12] indicated that a group smaller than 3 students might not contain enough diversity and be divergent to provide different thinking styles, while a group of 4 students seems to be ideal, diverse enough, and without excessive participants, allowing all of them to participate in the challenges. However, ideal student team size also depends on the type of challenge, equipment available for hands-on activities, infrastructure, and other variables and considerations that begin to appear and become important once challenges are being implemented. In this study, groups of four and three students were used. Furthermore, it is important to consider that student centered instruction is used to determine student current capabilities; knowledge centered instruction is a form of traditional lectures focused on teaching to achieve mastery of a subject; assessment centered instruction is used to build opportunities for students and teachers to get feedback on the learning progress; and community centered instruction builds a community that promotes learning in an appropriate community context [14,15].

2. Challenge-Based Instruction with Hands-on Activities

It has been determined that hands-on activities are required to promote STEM interest as a career path and to allow students to develop abilities to apply concepts and principles to a wide range of problems and situations [4]. Engineers and Scientists need knowledge and skills in areas such as hardware interfacing, sensors and actuators, electronics, data acquisition, controls, programming, and modeling and analysis of static and dynamic systems [3, 2]. They require adequate preparation to work on and design systems which are becoming increasingly electromechanical and multidisciplinary. Mechatronics is a combination of technologies and disciplines in engineering, electronics, intelligent control systems, and computer science, which together can contribute to design better and smarter products and processes [3, 4]. Modern industry and new technology have a high and increasing demand for skillful graduates with multidisciplinary experience [5, 6]. For example, at the University of Detroit Mercy, Yost et al. [7, 8] developed an "Introduction to Engineering Design" course and a "Pre-college Course in Mechatronics Applications" to engage students in multidisciplinary topics early in their career to increase their preparation and motivation for lifelong learning. Also, at Wright State University a "Model for Engineering Mathematics" was developed to increase retention rate, motivation and success in Engineering programs, and a significant part of their activities consists of hands-on and experimental practices [9]. Therefore, materials to implement challenges such as lectures, handouts, and assessment tools were developed in this study for students to participate in the classroom and hands-on activities in basic electronics and Mechatronics topics.

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Challenge-Based Instruction (CBI) is a research proven method to provide students with an interactive approach in learning and understanding new concepts. Different studies [10-17] have been performed in recent years and data have been gathered on how challenges should be used in order to appeal to students and, at the same time, enrich them by acquiring and retaining knowledge and understanding of the concepts involved in the challenges. As a common generalized practice, professors spend most of the class period lecturing about new subjects. While this trend has been around for a long time and has proven to work in some cases, the need for high quality graduates in STEM careers is ever growing and new methods of teaching students need to be implemented in order to ensure progressing interest in these subjects, increase the enrollment for these majors, and, consequently, increase the number of graduates and the quality of education in these areas. It is expected that in this project, most students will acquire and retain knowledge by going through the process of searching for solutions to challenging problems that require hands-on activities in which they may use and develop their abilities to work in teams and learn on their own.

One of the key findings in the book How People Learn (HPL) [15] is that most effective learning environments are the ones in which knowledge, assessment, learner, and community centered versus the traditional methods are implemented. Traditional methods provide an environment that is largely knowledge centered with some or little summative assessment and no attention to formative assessment. Summative assessment is a form of evaluation (quiz or test) that reviews what the students should have learned over a period of time. Formative assessment consists of activities that provide continuous feedback to the students, and it can also identify weaknesses so that the instructor and student could continue working together to accomplish better results. Formative assessment is a self-reflective process that intends to promote student attainments and continuous discovery of knowledge an adaptive expertise.

Challenge-based instruction and multidisciplinary hands-on activities were developed as a way to inform, motivate, and encourage students to stay in college and pursue STEM careers as well as to integrate knowledge and to follow the Star Legacy Cycle [17] approach in order to solve the challenges.

Following are fundamental steps in the Star Legacy Cycle [17] used in the challenges implemented in basic Electronics and Mechatronics:

- **Challenge:** A challenge is identified so that students encounter a realistic problem which is neither too trivial nor impossible for them to solve. The challenge needs to engage the students in the learning process in order to search, test, and to go public to provide a solution to the challenge.
- An assessment in the form of pre-test is given to the students to determine the level of knowledge they have about the concepts a specific challenge is addressing.
- **Generate Ideas:** Organized in teams, students are asked to generate ideas about the challenge and to communicate possible limitations or problems that need to be focused on in order to solve the challenge. The pre-test and the generated ideas are used by the instructor to determine misconceptions and the concepts that might require greater effort for students to understand.

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- **Multiple Perspectives:** A strategy used in the Legacy Cycle [17] to help students understanding the challenge is to use multiple perspectives, beginning with broad ideas from different sources and then narrowing them down to what the students need to accomplish and learn.
- **Research and Revise:** Following multiple perspectives, there is a step in the Legacy Cycle called research and revise, in which students do most of their formative learning by studying and summarizing lectures, handouts, and by acquiring information from other sources, such as textbooks and publications, and through asking questions to the instructor or other experts. Revising consists of performing research and completing class activities and/or homework assignments related to the challenge to ensure that the students are learning and progressing. Hands-on activities are part of revising knowledge and at the same time of testing student understanding. Formative assessment is performed during classroom or lab exercises in order to provide feedback to the students and instructor to correct deficiencies in the understanding of the challenge concepts.
- **Test Your Mettle:** Students test their mettle through quizzes, post-test, lab reports, exams, and/or demonstrations of the hands-on activity results, all of which could be summative assessment tools used to determine student grades. Students need to look ahead and reflect back and provide a solution to the challenge.
- **Go Public:** Finally, students go public with their findings by presenting and defending their solutions to the challenge and, at the same time, get feedback from their peers and instructor. These presentations also allow each student to see other solutions to the same problem to find out that there might be multiple ways to solve the challenges [13]. Part of going public is also demonstrating and explaining how their system works and presenting their findings and difficulties during the hands-on activity.

3. Example of a Challenge in Basic Electronics: Video Game System Problem

This challenge was implemented in the Introduction to STEM course at STC during the summer II term, in 2009, and it was also implemented in the Introduction to Mechatronics course at UTPA, during the 2009 Fall semester.

3.1 *Backwards Design*

This challenge was developed in order to get students involved in basic electronics in early STEM career courses, such as in the Introduction to STEM course. In general, to develop challenges for specific topics in a course, instructors need to take a backwards design approach starting by identifying all the target concepts that students are going to learn an understand by the end of the challenge. For example, Fig. 1 presents the dispersed concepts students are supposed to understand and integrate by the end of this challenge.

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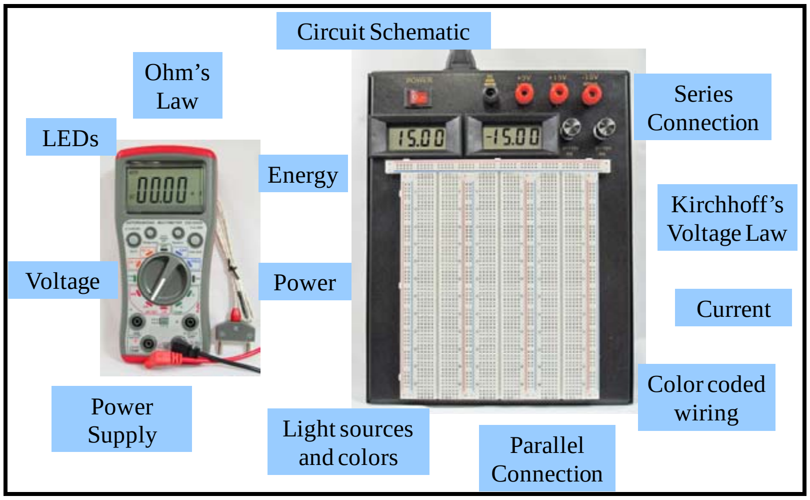

Fig. 1. Basic electronics concepts and components.

Following, the instructor needs to identify and describe the objectives, sub-objectives, difficulties, and real-world contexts associated with the challenge, and the ones for this specific challenge are presented next:

- Primary Objectives. By the end of this challenge, students will be able to:
  - Read a schematic and make basic electronic circuits using resistors and LEDs.
  - Understand and use breadboards, power supplies, and digital multimeters (DMMs).
- Sub-Objectives. The objectives will require that students be able to:
  - Use breadboards and power supplies.
  - Measure resistance, voltage, and current using a DMM.
  - Connect and measure resistors in parallel and series.
  - Apply Ohm's Law.
  - Understand and use LEDs.
  - Understand and apply Kirchhoff voltage law.
  - Compute power and energy consumption by resistors and LEDs.
- Difficulties. Students have difficulty with:
  - Correctly using the correct relationships and units between voltage, current, and resistance.
  - Correctly using breadboards, color code wiring, and power supplies to implement basic electronic circuits.
  - Correctly using DMMs to measure current, voltage, and other parameters because not only they need to know the correct lead connections but also setting the knob of the DMM to the right place and range.
- Real-World Contexts
  - There are many applications that use basic electronic circuits including resistors and LEDs: traffic lights, flash lights, street lights, monitoring systems, video game systems, among others.
  - Learning the mentioned concepts and acquiring hands-on experience in basic electronics are intended are the first steps to encourage students to pursue a career in a

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STEM field, such as electronics, measurements and instrumentation, mechatronics, and control systems.

3.2 Model of Knowledge

The instructor or challenge designer has to categorize and prioritize the target concepts of the challenge in a similar way to the example presented next for the basic Electronics challenge:

- Concept Map
  - Electronic components
    - Resistors, light emitting diodes (LEDs), and power supplies.
    - Parallel and series connection of resistors.
    - Units.
    - Symbols and diagrams.
  - Electronics Instruments
    - Breadboards and DMMs.
    - Measuring resistance, voltage, and current.
  - Ohm's Law
    - Voltage, current, and resistance relationships.
  - LEDs
    - Polarity, current limits, and connection requirements.
    - Power consumption and energy utilization.
- Content Priorities
  - Enduring Understanding
    - Resistors
    - LEDs and their correct connections.
    - Using a breadboard.
    - Ohm's Law.
  - Important to Do and Know
    - Correctly using a DMM
  - Worth Being Familiar with
    - Understanding power supplies.
    - Computing power and energy consumption by resistors and LEDs.
    - Kirchhoff voltage law.

3.3 Assessment of Learning

A plan has to be created to develop the assessment tools required to collect information that allows generating conclusions about student understanding of the targeted concepts. Next is the assessment plan for the basic Electronics challenge:

- Formative Assessment: it consists of practice activities, which should not count in a significant way as grades; however, it needs to provide feedback to the students and the professor in order to address any learning problems.
  - Pre-test.

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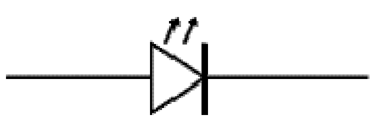
  - Classroom activities:
    - Adding resistors in series and parallel. Use Ohm’s law to determine expected currents and voltages in resistor circuits.
    - Study LED characteristics and ways of connecting them.
    - Compute power and energy consumption.
  - Lab Work
    - Using a breadboard.
    - Create circuits, measure currents and voltages.
    - Validate Ohm’s law and Kirchhoff’s voltage law.
    - Explain the results of the hands-on activities and the reasons why the system might not function properly.
- Summative Assessment: examples of this type of assessment are solutions to the challenges, post-tests, midterm exams, or final tests, which are usually part of the grade.
  - Prepare a report with answers to handout questions and with challenge conclusions.
  - Presentation or discussion to explain solutions to the challenge.
  - Post-test.

3.4 The Challenge

It is recommended to design challenges that engage the students by assigning them responsibilities and tasks related to real-world situations that include some expectations and consequences of their achievements to be obtained by understanding and solving the challenge. Fig. 2 presents the challenge used to instruct students about the example of basic Electronics concepts.

Challenge: Video Game System Problem

You are working for a videogame company and they are going to release a new system. You supervisor wants you to inspect LED circuits that are malfunctioning. It is your job to get the circuit up and running in order to meet the deadline to release the system. The company is planning to sell millions of games and your future job and salary depend on executing such plan at perfection.



Schematic symbol for an LED

Light emitting diode (LED)

Fig. 2. Challenge about Basic Electronics

Notice that even though the students are going to be presented with multiple perspectives to promote student engagement and to obtain broad ideas about LEDs, light, energy, and the other

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concepts of interest in the challenge, the challenge needs to focus the attention to the specific activities the students need to do.

3.5 Generate Ideas

Students were requested to brainstorm and write down ideas about the challenge, requirements to solve the challenge, importance of finding a solution, difficulties, and limitations. Some of the students' generated ideas are included below:

- Trial and error test; determine if LEDs can be fixed or must be replaced. Find which LEDs are malfunctioning.
- Circuit could have been connected wrong. Too much or too little energy. An interruption in the circuit. LED can be burned out. Wires could be damaged.
- The LED is broken. Current is incomplete. Faulty wiring. Too much power. Not connected properly.
- Switch a malfunctioning LED with a working one to test it. Connect it to a separate power source to test it.
- What does a schematic symbol do and mean. Fix connections. Fig. out how many Volts it takes to power the system.
- Connections are inverted. Not enough energy is being applied. Missing wire or connection.
- Not enough power, incomplete circuit. Current could be going the wrong way.

Most of these ideas were generated by students at the beginning of the challenge. However, because the generated ideas were collected together with the conclusions at the end of the hands-on activity, it seems that some students that did not generated enough ideas at the beginning of the challenge, completed some of this information during, or after, the hands-on activity. For subsequent challenges, the ideas generated by the students at the beginning of the challenge were collected to prevent them from adding other ideas afterwards.

3.6 Multiple Perspectives

The instructor, other experts, or other sources present the students with information about several common applications of basic Electronics, such as LED applications to traffic lights, computers, toys, displays, monitor, among others. Multiple perspectives are needed in order to develop a discussion to determine current or potential applications of the challenge concepts, and to identify their importance, advantages, and limitations. In the basic Electronics challenge, information was presented in lectures about commercial products with LEDs, the different colors of LEDs, and the conversation could be broad and take many different directions indicating that students might already be engaged in the subject. The instructor has to lead the discussion in the desired direction so that students focus and learn the concepts targeted by the challenge before they go on their own direction to discover additional complementary or distracting information. Internet is a common source of technical and non-technical information useful to provide students with multiples perspectives about challenge concepts.

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3.7 Research and Revise

In this part of the Legacy Cycle, the instructor proceeds to present traditional lectures to explain concepts, work with examples, and implement classroom activities. In the basic Electronics challenge, the instructor presented a lecture about breadboards, power supplies, digital multimeters (DMMs), resistors, and LEDs explaining how they work and what are the requirements and guidelines to use them correctly. In addition, a handout with additional information about the components to be used in the hands-on activity for the specific challenge was provided to the students. An example section of this handout is in Fig. 3. Notice that the handout has sections for students to collect experimental information that might be used for subsequent analysis of results and validation of theoretical computations.

Students need to dedicate some time in this part of the challenge to study the handout to determine the steps, components and materials required during the hands-on activity. Students also need to study the lecturers, the background information presented in the handout, and look for additional information in the library or internet, to understand the challenge concepts and the whole purpose of the hands-on activity. This might be a difficult step to achieve in a single day challenge during class time, therefore, students might have to do homework before and after the class time to satisfactorily achieve a solution to the challenge and understand the targeted concepts.

3.8 Test Your Mettle

In this part of the challenge, students are required to demonstrate that they understand the challenge concepts. Following is a list of possible activities that can be performed to test students' mettle:

- Students perform experiments (work in the lab to learn through hands-on activities). Instructors ask questions in order for students to explain their experimental results and understanding of concepts.
- Post-test.
- Answer the questions in the handout. Another example of a handout section where students need to indicate the results of measurements and validate a theoretical Law is presented in Fig. 4.

3.9 Go Public

In is an important step that students go public to complete the Legacy Cycle approach to solve the challenges. Going public might impose a positive degree of accountability for the students to work and dedicate satisfactory effort in the classroom and lab to achieve results that they can proudly share with others. Examples of going public activities in the basic Electronics challenge are:

- Students demonstrate the results of their hands-on activities to the instructor and other students. In the case of the basic electronics challenge, students show and explain how their electronic circuits work.

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- Students turn in the results and conclusions, including possible solutions to the challenge.
- Students show pictures, videos, and/or presentations.

Ohm's Law, Voltages, Currents, Resistors, and Hookup Wires

Hookup wires are solid copper wires with colored insulation.
Connect some resistors in series and other resistors in parallel and determine the resultant resistor in each case.

Use 5V and the ground, or reference voltage, and validate Ohm's law using one or several resistors: $V = i \cdot R$. Also, the power dissipated by the resistor can be found using these equations: $P = V \cdot i$ or $P = R \cdot i^2$.

Use red wire for 5V and black wire for ground. Be sure the power dissipated in each resistor is not more than 0.1 Watts to avoid damaging them.

<u>Put results here, use the correct units:</u>

R_1 = ________ ; R_2 = ______________

R_{series} = ________ ; R_{series_DMM} = __________

$R_{parallel}$ = ________ ; $R_{parallel\_DMM}$ = __________

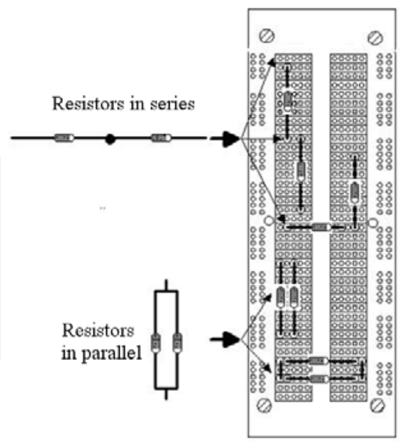
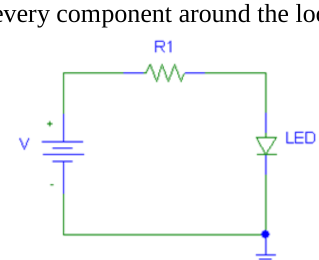


Figure 2. Resistor Connections

Fig. 3. Section of handout for hands-on activity

Simple LED Circuit and Kirchhoff's Voltage Law

a. Create the LED circuit set up as shown in the following schematic try to make your circuit look as the schematic. LEDs have polarity. Once you have completed the circuit, measure the voltage across every component around the loop and validate Kirchhoff's voltage law.



V_{LED} = ________

V_{R1} = ________

Fig. 4. Section of handout to test students' mettle and validate theoretical results.

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3.10 Challenge Conclusions: Look Ahead and Reflect Back

Students make recommendations and conclusions. Students were asked to explain reasons why the LED of the video game system is not properly working. Next are examples of conclusions students reached during this challenge:

- The resistors are not of the correct resistance.
- The wires were connected at the wrong places. Always be sure to have your multimeters for the appropriate channel.
- The resistor might be defective. The LED was installed wrong. The LED was burned out.
- Improper connection. Bad power source. Missing resistor. Broken LED. Circuit broken.
- Not connected properly. Loose connections. Short circuiting. AC flow instead of DC.
- Ground wire was connected to the wrong place. The resistor was not properly aligned with the LED. The voltage wire was not properly connected with the breadboard. The voltage was too high and burned out the LED.
- The LED short side maybe is not placed in ground. The resistor might not be strong enough; this would burn out the LED. Voltage in wire might have been too high or too low.
- I learned that resistors can be in series or parallel. The circuit had to be closed for the LED to light up. The short leg of the LED had to be grounded. I learned current was the same through resistor and LED in circuit. I learned how to use different electrical formulas. I learned how to power breadboards.
- The LED and the resistor did not connect to a power supply. The current was not passing through the LED and resistor.

These student conclusions show that they correctly explain possible causes of LED circuits malfunctioning, according to what they experienced during the hands-on activity and what they learned in all steps of the Legacy Cycle approach followed to solve the challenge.

4. Assessment of Learning

The following true and false questions were used in the pre- and post-test in the basic Electronics challenge in order to estimate student understanding of the targeted concepts before and after the challenge.

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Pre-Test/Post-Test

Part 1. True or False

1.	Ohms are the units of voltage.	T □ ; F □
2.	Amperes (A) are the units of resistance.	T □ ; F □
3.	Ohms are the units of resistance.	T □ ; F □
4.	Volts (V) are the units of voltage.	T □ ; F □
5.	Amperes are the units of electric current.	T □ ; F □
6.	Volts is equal to Amps x Ohms.	T □ ; F □
7.	Power is current x resistance.	T □ ; F □
8.	Power is measured in Watts.	T □ ; F □
9.	Energy is Power/time.	T □ ; F □
10.	Energy is measured in Watts x hours.	T □ ; F □

Fig. 5. True or false part of the pre- and post-test.

The following multiple choice questions were also used in the pre- and post-test in the basic Electronics challenge in order to estimate student understanding of the targeted concepts before and after the challenge.

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Pre-Test/Post-Test

Part 2. Multiple Choice

11. The resultant resistance R_r of two resistors R_1 and R_2 in series is:
    a) Less than R_1 and less than R_2
    b) Greater than R_1 and greater than R_2
    c) Equal to half of R_1 plus R_2
    d) Equal to $1/R_1 + 1/R_2$
    e) $1/(R_1+R_2)$
12. The resultant resistance R_r of two resistors R_1 and R_2 in parallel is:
    a) $R_1 + R_2$
    b) Greater than every resistor R_1 and R_2
    c) Equal to $1/2*(R_1+R_2)$
    d) Equal to $1/(1/R_1 + 1/R_2)$
    e) $1/(R_1+R_2)$
13. To measure current, a multimeter has to be connected
    a) in series with the path where the current is to be measured.
    b) in parallel to the path where the current is to be measured
    c) between ground and one end of the path where the current is to be measured
    d) same as for checking continuity
    e) same as to measure voltage
14. To measure voltage, a multimeter has to be connected
    a) in series with the element across which the voltage is to be measured
    b) in parallel to the element across which the voltage is to be measured
    c) between +5V and one end of the path where the current is to be measured
    d) same as for checking continuity
    e) same as to measure current
15. An LED is:
    a) a lightly eminent danger.
    b) a limited emissions display.
    c) a lots of efficient discounts.
    d) a new type of resistor.
    e) a light emitting diode.

Fig. 6. Multiple choice part of pre- and post-test.

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Fig. 7 presents the results of the pre- and post-test in the basic Electronics challenge with 53 students in the DEEA program at STC during summer II term, in 2009.

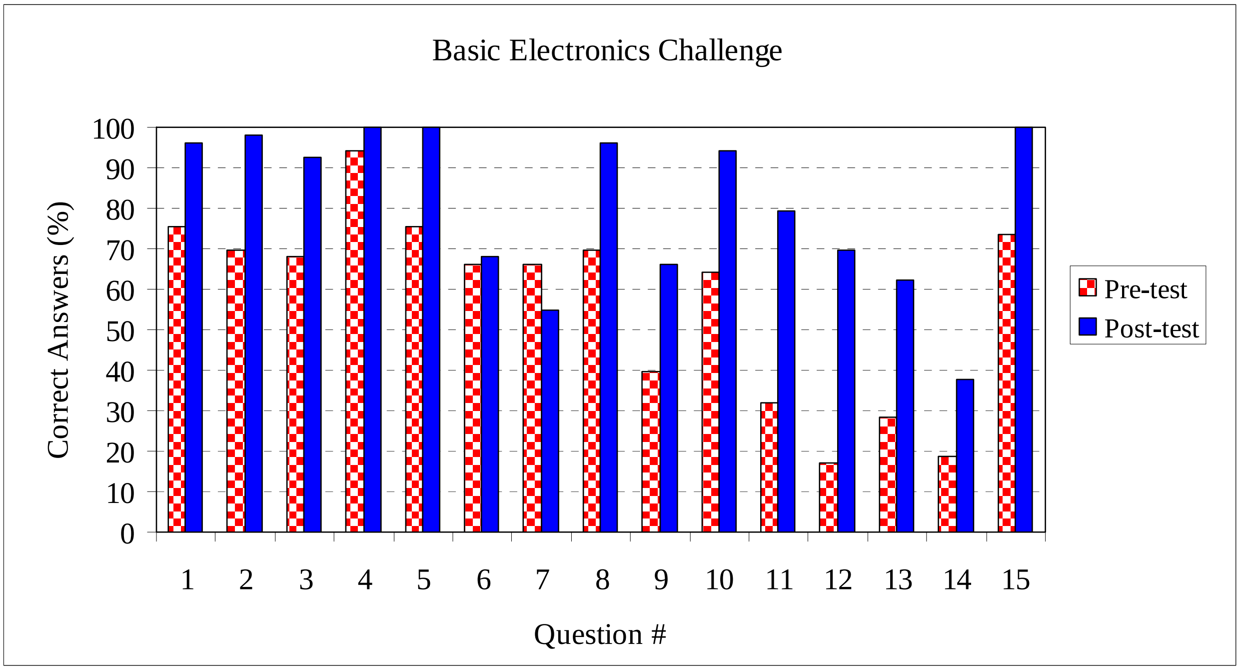

Fig. 7. Results of pre- and post-test.

As can be noticed in Fig. 7, students significantly acquire and retain knowledge in the area of basic electronics using challenge-based instruction. The overall effect of the challenge was to increase student knowledge of basic electronics. Questions 1-5 and 8 demonstrated the students' ability to apply appropriate units to given quantities in basic circuits. Prior to the challenge, the average percentage of students answering correctly was about 70% for these questions, with the exception of question 4. Being True/False questions, 50% would be expected to answer correctly if just guessing; hence, it is likely many students were unfamiliar with these units. After the implementation of the challenge, the percentage of students answering correctly increased to about 95% or better with question 4 and 5 being answered correctly by all students. This represents a significant gain.

Questions 6, 7, 9, and 10 demonstrate students' ability to relate basic concepts of circuits to one another; specifically voltage, current, and energy. Prior to the challenge, the average percentage of students answering correctly was about 65% with question 9 being answered correctly by only 40% of students. Again, it appears that many students are unfamiliar with these concepts prior to the challenge. Upon implementation of the challenge, it is seen that questions 9 and 10 show a significant gain (25% increase in both) with students demonstrating a better understanding of the relationship between power and energy. Questions 6 and 7 do not show any significant change in

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the number of students answering correctly, however. This may be due to the fact, in question 6, students learned than voltage is equal to current times resistance and the corresponding association that Volts are equal to Amperes times Ohms was not completely understood by some students. Question 7 gives contradictory results with students answering correctly at a higher percentage on the pre-test than on the post-test. The reason for this is assumed to be the fact that this relationship was not used at all in the lecture or hands-on activity of the challenge; and in the background of the handout, it was indicated that power equals current squared times resistance, which significantly differs from the question conceptually but slightly in appearance.

Questions 11 and 12 demonstrate students' knowledge of equivalent resistance in parallel and series circuits. Prior to the challenge the average number of correct answers where around 25%. A correct answer response of 20% would be expected if the students where guessing; hence, it appears that students had no prior knowledge of this concept. After the challenge was implemented, the number of correct responses increased to an average of 75% of students. This represents a significant increase.

Finally, questions 13 and 14 demonstrate students' knowledge in the use of multimeters to make measurements in basic electrical circuits. Prior to the challenge, the percentage of students responding correctly was an average of about 25% demonstrating no prior knowledge. After the implementation of the challenge, there was only a moderate increase in the number of students who could describe the use of a multimeter based on a correct answer response. It appears that approximately half of the class where able to describe measurements using a multimeter despite its extensive use in the hands-on activity. This may happen because some students begin to rely on their teammates to do the measurements, then, only some students grasp a satisfactory understanding of how to connect and use the multimeters.

A drawback of true or false questions is the high probability of answering the question correctly just by guessing. Therefore, multiple choice questions are recommended for future assessments. However, it is important to select the answers of the multiple choice questions in a way such that there is not an obvious correct answer as one of the choices.

A point of future investigation might be to compare the effects of challenge-based instruction of basic Electronics concepts to that of traditional lab-based basic Electronics activities.

4.1 Affect Survey

An affect survey was performed to determine students' opinion about the challenges in basic Electronics and Mechatronics in the new Introduction to STEM course at DEEA in STC. Following are the results obtained with the affect survey applied to the Electronics/ Mechatronics part of the course:

Affect Survey

Please carefully read the questions and provide us with **<u>an assessment of the Electronics and Mechatronics Challenges and Activities</u>** in this course: basic Electronics, Electronics, Mechatronics, and Renewable Energy.
Use the following scale and circle a number for each corresponding question:

1. Strongly disagree
2. Disagree
3. Neither agree or disagree
4. Agree
5. Strongly Agree

I was able to recall previous knowledge and apply it to my challenge
1 2 3 4 5

I enjoyed the Challenge Based Instruction and the overall experience of the legacy cycle
1 2 3 4 5

Working together with classmates helped my overall learning experience
1 2 3 4 5

These challenges did nothing to enhance my learning experience
1 2 3 4 5

These challenges helped me apply my critical thinking skills in order to solve the problems.
1 2 3 4 5

Fig. 8. Affect survey for basic electronics and Mechatronics challenges.

The results of this affect survey for four challenges that were implemented in the area of Electronics and Mechatronics are presented in the following Fig.. The survey could be eliminated if the response of question 4 contradicts other responses, meaning that the student did not read the questions.

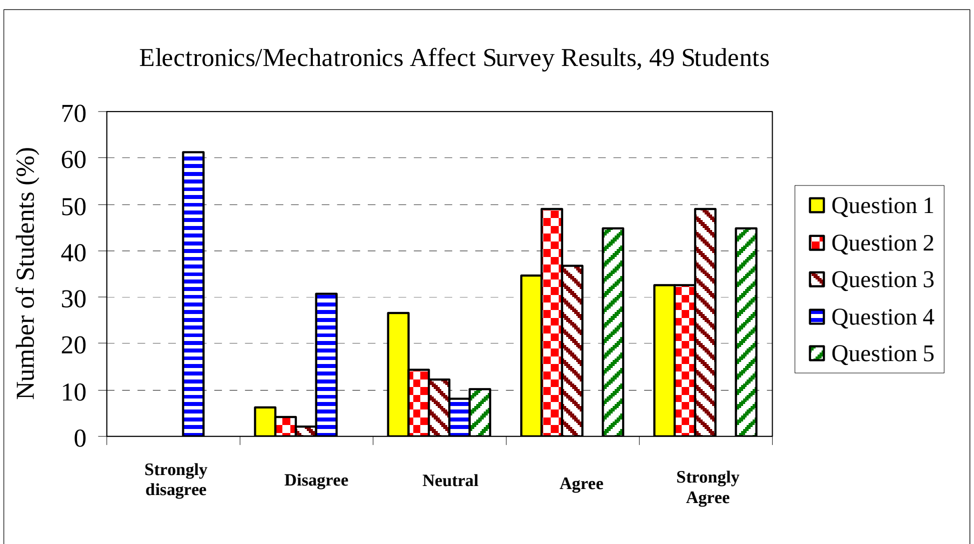

Fig. 9. Affect survey results for basic electronics and Mechatronics challenges.

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Except for question #1 of the affect survey, the majority of the students indicated to "agree" or "strongly agree" in a positive way towards the experience they had in the Electronic/Mechatronics challenges as part of the Introduction to STEM course. Disagree or neutral as an answer for question #1 is a reasonable response because it is expected that some students do not recall any previous information related to the challenge.

5. Conclusion

Several challenges have been developed and implemented for instruction in basic Electronics and Mechatronics topics. This paper described the challenge-based instruction approach that was followed and the steps and activities that were implemented for a specific challenge that targets concepts in basic Electronics. In addition, assessment results of pre-test, post-test, and affect survey were also presented in this paper. Examples of the materials used for the challenges with hands-on activities and assessment tools developed to determine the students' understanding of the concepts targeted by the challenge are also included. Hands-on activities were important components of each challenge and they are described in this paper. This work has been developed as part of a College Cost Reduction Access Act (CCRAA) grant from the US Department of Education to UTPA in collaboration with STC. The novelty of the initiative presented in this paper is developing and implementing CBI with hands-on activities in basic Electronics and Mechatronics topics in a new early career Introduction to STEM course, not only to improve the quality of STEM education but also to improve engagement, motivation, understanding, and retention of knowledge; and consequently, increase or maintain high the retention rate of STEM students. Other challenges that have been implemented in this project follow a similar structure and procedure to the example presented on this paper.

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