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THE ENGINEERING DESIGN GRAPHICS

Journal

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About the Journal
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Manuscripts submitted for publication are subject to peer review by the EDG Journal editorial review board. The views and opinions expressed herein are those of authors and do not necessarily reflect the policy or the views of the EDGD.

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Message from the Editor

Recent Initiatives

By Robert A. Chin
East Carolina University

A couple of initiatives have been undertaken since the last issue. First, we are attempting to collect and interpret data on the performance of the journal. Second, with the publication of this issue, we welcome several new staff members.

The new staff members include two assistant editors and three reviewers. The three new reviewers include Dr. Hosein Atharifar, Assistant Professor, Department of Industry & Technology, Millersville University of Pennsylvania; Dr. Kevin Devine, Assistant Professor, Department of Technology, Illinois State University; and Dr. William (Ed) Howard, Assistant Professor, Department of Engineering, East Carolina University. Dr. AJ Hamlin, Lecturer, Department of General Engineering, Michigan Technological University, joins the EDGJ editorial board as an assistant editor assisting Nancy Study in her duties managing the review process. Dr. Carolyn Dunn, Assistant Professor, Department of Technology Systems, East Carolina University, joins the EDGJ editorial board as an assistant editor with copyediting, layout editing, and proofreading responsibilities.

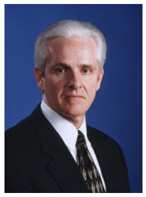
In an attempt to wrap our arms around the Journal's performance, since it is now an online journal, Google Analytics (GA) was adopted to provide us with performance statistics. GA is a no-cost service offered by Google that provides users with website visitor statistics that can be used to improve services to our readers and authors. In an attempt to get a sense for our performance, a quick glance was taken and a comparison was made with statistics for another journal hosted by East Carolina University's Emerging Academic Initiatives office—the Journal of Curriculum and Instruction (JoCI). The descriptive statistics associated with the following measures appear in Table 1: visits, unique visitors, page views, new visits, visits from countries/territories, and visits originating from the United States. The reader is cautioned in comparing the statistics. The data for the JoCI were collected from Aug 1, 2007 through May 2, 2010. The data for the EDGJ were collected from Sep 27, 2010 through Nov 12, 2010.

Table 1. Performance Comparisons

	JoCI	EDGJ
Visits	32,452	1,999
Unique Visitors	22,843	1,791
Pageviews	157,094	4,753
New Visits	70.10%	89.49%
Visits from Countries/Territories	148	87
Visits from the United States	24,162	729
Proportion of Visits from the US	74.50%	36.50%

Periodic updates will be provided in future columns.

Message from the Chair



65th Midyear Message

Timothy Sexton
Ohio University

We just finished our 65th midyear meeting in Houghton Michigan hosted by Michigan Tech. Special thanks go to our general chair Sheryl Sorby, and our co-chairs Amy Hamlin and Norma Veurink for being such welcoming hosts. As suggested on one of the postcards in our meeting packet, Houghton is not the End of Earth but simply two miles from it. For many of us Houghton may be the closest we will ever get to the Arctic Circle. Despite our apprehensions, Houghton turned out to be a beautiful setting for a midyear meeting and the Michigan Tech "girls" did a fantastic job.

The pre-conference activities were well planned and lots of fun. These included a tour of the Quincy mine which was the deepest mine in 1945. We descended into a mine which reached a record depth of 9260 feet in 1945. Later that evening we dined at the exclusive Miscowaubik Club restaurant. It was built as a social club by the copper barons in 1903. Sheryl Sorby later hosted us for dessert at her palatial estate. Sunday brought the Copper County tour of the Keweena Peninsula. The scenic countryside made one appreciate the beauty of Houghton's surroundings.

Reflecting on the proceedings one can find a firm foundation in past research, present status, and the future direction of our most important task of improving students' spatial visualization abilities. Papers illustrated methods for improving spatial abilities using intervention courses designed for poor spatial test performers. Others presented new directions using grants to help train high school math teachers increase their student's knowledge of geometry and spatial abilities through the use of 3-D solid modeling software. Other research addressed balancing face-to-face versus on-line graphic instruction which is an efficacy question of the future. And whenever there is a paradigm shift in how we teach graphics, there's a conflict. One paradigm shift examined the struggle with switching from curriculum based technical drawing to design and communication graphics when training teachers. Two papers addressed the problem of introducing design problems into the curriculum. The first addressed the problems encountered by presenting freshman with a hands-on design problem and then waiting until a student's senior capstone course to present another practical real world design problem. The second discussed the difficulty of finding design problems at the first year level of engineering knowledge as well as being challenging, realistic, and interesting to students of different engineering majors. As always there were papers that introduced new technologies in our field. A promising technology described the use of 3-D laser scanners that generate a "point cluster" upon which a surface model is based. This surface model can be translated into a STL file or be used to generate a solid model. This is a powerful tool for reverse engineering a part. But the most exciting development of this midyear meeting is the number of papers presented by members from outside the division. These individuals were invited to present papers they presented at the annual ASEE conference and five accepted. These five papers represented 28% of the papers presented at this year's midyear meeting. All five papers were from the Design Engineering Education Division. Our division needs new blood in order to continue our mission of fostering the power of graphics in engineering and technology students. As our division continues to gray, we all need to think of new ways to grow our membership. Inviting non-division members to present papers is an ingenious method. We would not be in this division if we were not creative thinkers so bring forward any new ideas to grow our membership even if it may seem difficult to implement.

We all enjoy participating in the midyear because of its intimate size. It is a time to foster personal relationships, grow professionally, and remember, as individuals we look a lot less nerdy when we are together as a group.

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Officer Nominees

Nancy E. Study
for Vice-Chair

Nancy E. Study is an Associate Professor in the Department of Engineering and Technology at Virginia State University where she teaches courses in engineering graphics, facility planning, and cost estimating. She has been active in the Engineering Design Graphics Division of ASEE since 1999, has presented a number of papers at the midyear meetings and annual conferences, and has served as Associate Editor of the Engineering Design Graphics Journal since 2006. As a co-author, Nancy is a previous winner of the EDG Journal Editor's award.

Nancy has a B.S. from Missouri State University and M.S. and Ph.D. from Purdue University. Her research interests are in visualization, haptics, and the integration of educational technology in STEM education. Her most recent work has focused on improving visualization abilities of minority engineering and technology students. She is also a member of Phi Kappa Phi and Epsilon Pi Tau honorary fraternities.

Nicholas Bertozzi
for Director of Communications

Nick is a Professor of Engineering at Daniel Webster College (DWC) and Dean of the School of Engineering and Computer Science (SECS). His major interest over the past fourteen years has been the concurrent engineering design process, an interest that was fanned into flame by attending an NSF faculty development workshop in 1996 led by Ron Barr and Davor Juricic. As a result of this workshop, in 1998 a three-semester engineering design sequence was introduced in DWC's two-year engineering program. The evolution of this program is described in the article, 'Implementation of a Three-Semester Concurrent Engineering Design Sequence for Lower-Division Engineering Students', and was published in the Winter 2007 American Society for Engineering Education (ASEE) Engineering Design Graphics Division (EDGD) Journal. The sequence was well received by the DWC engineering students and in 2005 the College introduced BS degrees in both aeronautical and mechanical engineering. The new BS programs both contain a five-semester design sequence. Engineering graphics and concurrent engineering are developed and exercised through-out the new curriculum. In 2006 DWC was accepted into the CDIO collaborative (www.cdio.org) and in July 2010 the aeronautical engineering program received ABET accreditation. A site visit for the mechanical engineering program is planned for fall 2010. Nick has a particular interest in helping engineering students develop good communications skills and has made this a SECS priority. Over the past six years he and other engineering and humanities faculty colleagues have mentored a number of undergraduate student teams who have co-authored and presented papers and posters at EDGD and other ASEE, CDIO, and American Institute of Aeronautics and Astronautics (AIAA) meetings as well. Recent DWC student team awards include the 2009 ASEE EDGD Chair's Award, first place in the team paper competition at the AIAA New England Region Student Conference, April 2010, second place in the student project poster competition at the ASEE Northeast Section Conference, May 2010, and tied for second place in the student project competition at the 2010 International CDIO Conference, Montreal, June 2010. He was delighted to serve as the EDGD program chair for the 2008 ASEE Summer Conference and is currently serving on the ASEE EDGD executive committee as the Director of Communications.

2010 Distinguished Service Award

Introduction

Ron Barr presenting Ron Paré with his DSA.

The recipient of tonight's Distinguished Service Award has been a member of ASEE for over forty years. During that time, he has taught Engineering Graphics and Descriptive Geometry at Universities in three different states. His loyalty and dedication to the Engineering Design Graphics Division is underscored by his service as a past Division Chair, and as Program Chair for numerous EDG midyear meetings going back three decades. A special distinction concerning tonight's ceremony is that our recipient's father received this same Distinguished Service Award 34 years ago. In addition to an accomplished career as a college educator and author, our recipient has served his country both in active Army duty, including a tour in Vietnam, and in the U.S. Army Reserves, attaining the rank of Colonel. It is my pleasure to introduce a long-time colleague and humble servant of the Engineering Design Graphics Division, a true American patriot, and a fellow citizen of the state of Texas, Ron Paré.

Ronald E. Barr

Presentation Speech

Ron Paré making his accecptance speech

Thank you to Division Members for honoring me with this award and to my family for allowing me to do the things away from them that allowed me to earn you recognition. Many of you know that in addition to my teaching career, I served twenty eight years in the Army Reserve. The Army and ASEE events caused me to miss a lot of family birthdays and other activities. Without Ann's, Julie's and Wayne's approval, I would not be here today.

Personal Comments

I grew up in a very competitive and athletic family that competed in many sports and against each other.

My dad, who received this same award shortly after I began my teaching career and became involved in EDG, gave up swimming when my sister Merilyn beat him when she was 11. Dad also gave up golf when my younger brother Steve beat him when he was in college and I gave up teaching drafting briefly in the 70's when I realized I would never be able to draw perfect circles at the blackboard like he could, (thank goodness for PowerPoint). I also gave up Baseball while in Little League when my younger brother Phil hit a home run off my mediocre fast ball. One sport my dad didn't ever stop playing until he died was tennis, even though my sister was a Chicago Junior Champion.

It is said that your legacy is your children. My dad has a pretty good legacy

My Dad was a – Teacher first, Engineer second, and Artist as a hobby. His legacy is great.

His 4 children - 2 Engineers, 3 Teachers and 1 Teacher/Artist.

I'd say dad left the world quite well off.

He introduced me to ASEE when I was a teenager by taking me and the rest of us Paré children to Summer Conferences all over the country. Before I was a junior in High School our one month long ASEE Convention adventures had introduced me to most of the natural beauty of the United States.

I tried to the same with my two children and I recommend to all of you doing the same with your families.

I think I was always going to be an Engineering Graphics Teacher. While Ann and I both loved the Army, the Vietnam War made me decide to cut my active duty Army career 17 years shorter than we originally planned and I began teaching Engineering Graphics at Cal Poly Pomona with Dale Galbrath (and EDG awardee)and Wally Reynolds.

I tried College Administration for a while but I missed the classroom. When my Dad asked me to become the junior officer with the 6th Edition of the Descriptive Geometry Textbook, that was the final impetus to go back to teaching Graphics full-time. It also resulted in moving from the West Coast to Houston in 1983. Since I was in an Engineering Technology Department, it took a few years to get back involved with the Graphics Division. While I always attended the Graphics Banquet at the summer convention, I rarely got to attended Mid-Year Conferences because they often overlapped with the ET Division's CIEC meeting.

Distinguished Service Award

The year I was chair of EDG I emphasized the people of the Division in my Journal Articles. I would like do the same thing by highlighting the DSA awardees of the Division. I have prepared a Summary Power Point which I would like to now share with you. The photos are scans from issues of the Journal. This is audience participation, if you recognized a photo please call out the awardees name.

[Power Point Presentation]

I would like to close with some advice to the division.

First, on my last cruise, our duplicate bridge leader always stressed that "Minors are for the Birds". If you play bridge you know what she meant. In organizations that depend on volunteers, like EDGD, it is my opinion that "Contested Elections are for the Birds". I have always believed this but my review of the Journals to prepare the Power Point just reinforced my opinion. Numerous years I saw individuals who served the Division in numerous appointed and elected positions stop all involvement when they lost an election, usually Chair Elect. So I recommend the current EDG Board consider uncontested elections of officers. Some provision for nominations from the floor would need to be worked out, put I think the Nominating Committee should but up the one best willing to serve each year.

Second, when I first got involved, there were three things that made this division great. Only two remain and I believe all three are needed.

1. We are only one of two divisions that publish a Professional Journal.

2. We are the only division to have a standalone Mid-Year Technical Conference.

3. We were the first division to have a Student Design Display. When I was first involved with the Division, I served on the Design Display Committee; there were 120 entrees each year. It was one of the events highlighted by the society at the Summer Conventions.

We were very visible to the entire Society. A question, how many at this banquet have a design component in one or more of their classes. Second question, how many have a design component that requires a report or graphics be turned in. With this almost unanimous response, how could it be that we as a division let this activity die?

Food for thought for the next EDG Board.

Thank you again for honoring me with this award.

Ronald Paré

A Virtual Embedded Microcontroller Laboratory for Undergraduate Education: Development and Evaluation

Jeffrey J. Richardson & Nicoletta Adamo-Villani
Purdue University

Abstract

Laboratory instruction is a major component of the engineering and technology undergraduate curricula. Traditional laboratory instruction is hampered by several factors including limited access to resources by students and high laboratory maintenance cost. A photorealistic 3D computer-simulated laboratory for undergraduate instruction in microcontroller technology was developed to address these issues. The virtual laboratory includes a realistic representation of devices and components used in a traditional laboratory setting. The virtual laboratory requires the students to engage in the same processes as the traditional laboratory. An initial formative evaluation of the virtual laboratory environment (VLE) was conducted with a group of 42 undergraduate students enrolled in an introductory microcontroller course at Purdue University. Findings show that students perceived the VLE experience comparable to the physical laboratory experience; in addition, they thought the VLE was easy-to use, engaging and useful. In the paper we describe the development of the VLE and report and discuss the results of the evaluation.

INTRODUCTION

Laboratory experiences represent fundamental instructions for electrical and computer engineering technology students. Laboratory exercises allow the students to build electronic circuits, modify design parameters and measure the resulting effects. Embedded microcontroller laboratory experiences are similar in that the students construct circuits, create software to accomplish the desired task, and then test the software. In order to reduce the chance of errors within the physical electronic circuits, the Electrical and Computer Engineering Technology department at Purdue University has turned to a set of pre-built laboratory peripheral boards that include: a lights and switches board, a scanned keypad board, a multiplexed 7-segment display board, a stepper motor board, a liquid crystal display board, a slide potentiometer and joystick board, and a synchronous serial interface board. Having pre-built hardware allows the students to focus their time and attention on the embedded microcontroller hardware and software, the real focus of an embedded microcontroller course. However, the pre-built laboratory peripheral boards add a significant cost element to the course. This additional cost prevents typical students from acquiring the hardware necessary to work on laboratory exercises from their individual residence. The cost associated with laboratory peripheral boards also prevents the department from having enough development boards to make them available to the students outside of their normally scheduled laboratory sessions. In order to help solve these issues, a virtual laboratory environment was created using state-of-the-art 3D technology that provides a photorealistic representation and simulation of the actual embedded microcontroller development board and the peripheral boards available to the students during a normally scheduled laboratory. The virtual laboratory requires the students to perform the same type of steps that are performed during a regular laboratory session to make interconnections between boards, connections to the power supplies, and even requires the parameters on the virtual power supply to be adjusted by manipulating the power supply controls.

BACKGROUND

Traditional laboratory instruction has several limitations including: limited availability to the hardware and resources, high laboratory maintenance and operational cost, and limited assistance for students with disabilities such as students with limited motion or visual impairments [1]. Simulation tools and other multi-media technologies have proven valuable in the learning process and have been documented in many numerous publications [2]. Research has shown that the use of simulation tools reinforces learning and leads to performance improvements in a variety of disciplines [3]. A comprehensive literature search produces numerous examples of virtual laboratories across a wide variety of disciplines including various engineering and science laboratories, microelectronics, earthquake simulators, mechanical stresses, etc [4-9]. Commercial products such as MultiSIM are also available for use in simulation of electronics circuits [10]. At Temple University, a virtual laboratory was developed to assist students with limited mobility of their hands and upper bodies to perform electronic laboratories through a virtual reality environment instead of using the physical laboratory hardware [5].

A virtual laboratory environment that includes a highly realistic representation of the devices, components, and processes required to complete a laboratory activity can provide the mental engagement necessary to transfer the activities from within the virtual laboratory to the physical laboratory [1]. A photo-realistic virtual laboratory environment can be employed to reduce the high operational costs of a traditional laboratory environment and when web-enabled, or delivered through removable media such as a CD, DVD, or Flash Drive. A virtual laboratory can be accessed by students at any time day or night and can also be utilized to provide laboratory education at a distant location [1].

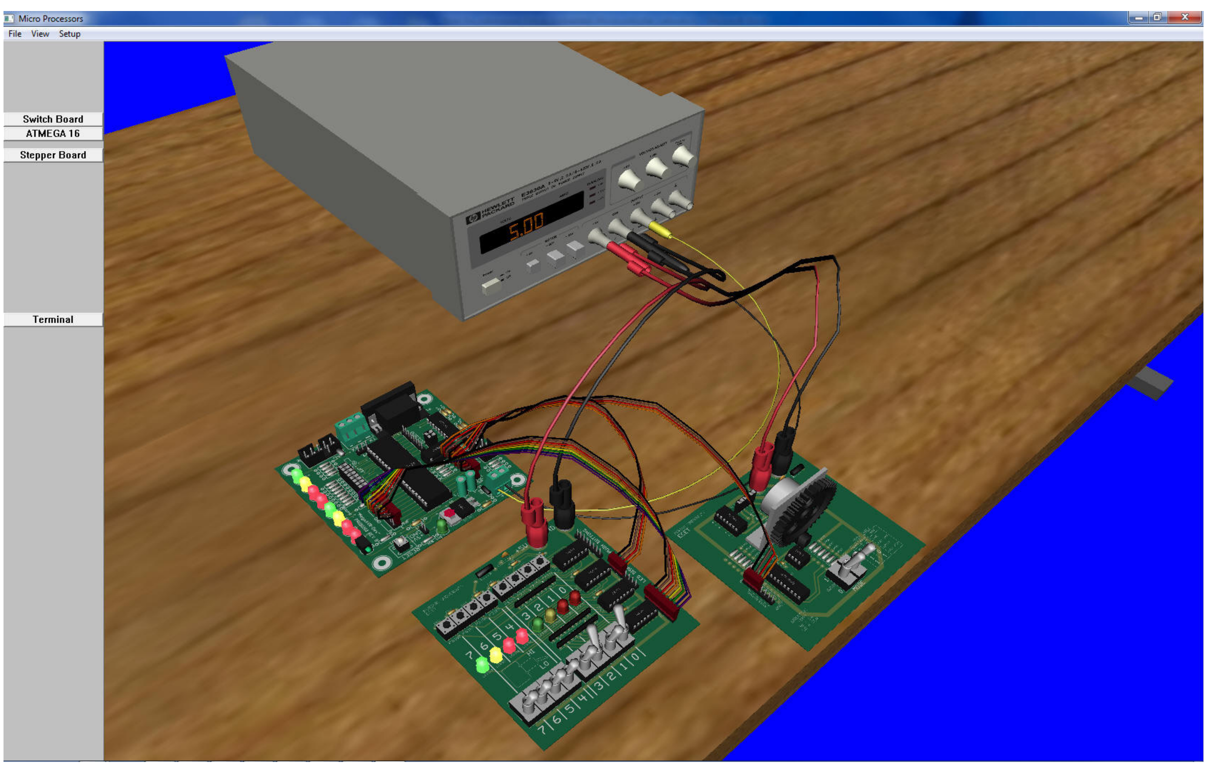

Figure 1 – Screenshot of the Virtual Laboratory

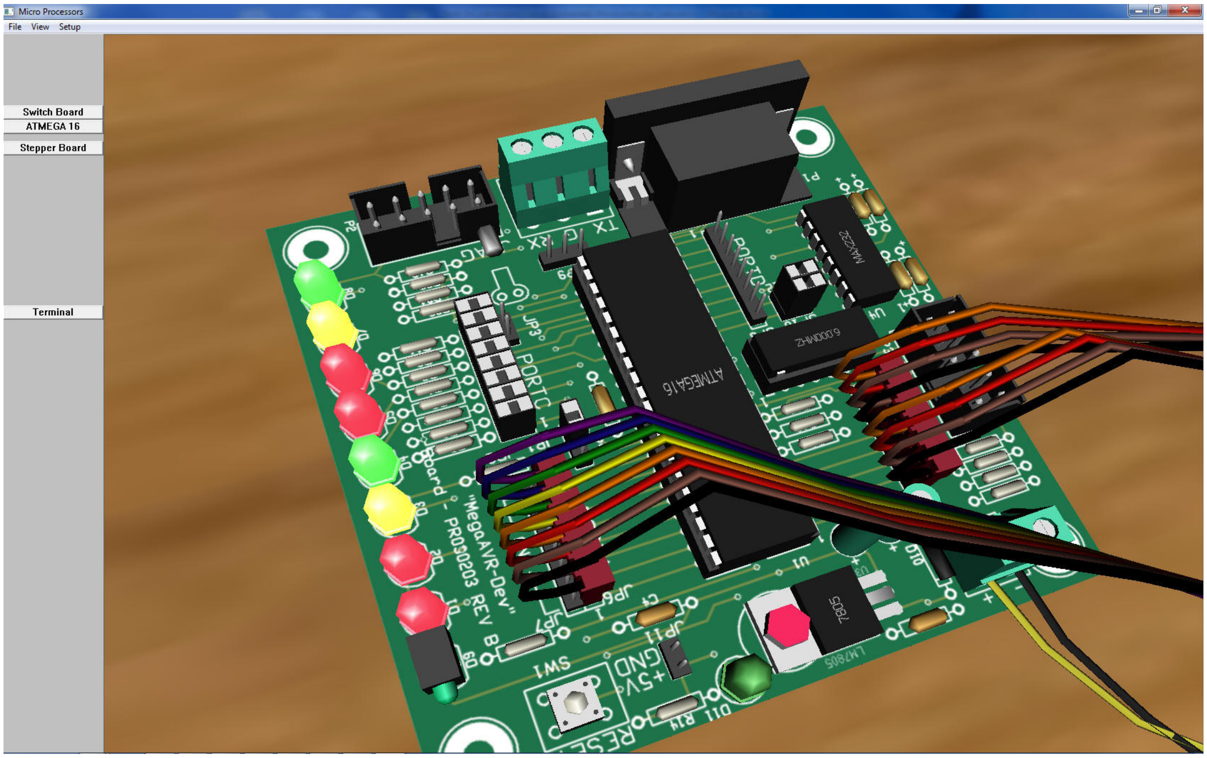

Figure 2 – Screenshot of the Microcontroller Development Board

The object of this research effort was to create a virtual laboratory environment that utilizes state of the art, photorealistic 3D computer graphic technology to emulate the devices and processes required to complete an embedded microcontroller laboratory activity within the Electrical and Computer Engineering Technology Department at Purdue University. Once the laboratory environment was created and validated, the next step would be to utilize the laboratory environment to assist students with visual or physical impairments overcome obstacles to their education.

THE VIRTUAL LABORATORY ENVIRONMENT

The virtual laboratory environment provides extremely realistic representations of the physical laboratory equipment utilized during a typical experiment as shown in figure 1. The configuration shown includes the main microcontroller development board, a lights and switches board (primary device utilized for input and output operations), a stepper motor development board, and a benchtop power supply. Additional development boards are also available and include a liquid crystal display, 7-segment display board, and a scanned keypad board which are not shown.

To maintain a high level of detail and scale relationship, all of the 3D models of the development boards were modeled from the actual technical drawings of the physical laboratory hardware. Once the actual sizes and relationships were established of the development boards, photographs of the physical boards were utilized to complete the models with special attention given to the level of details within the development boards. Figure 2 shows a close-up view of the microcontroller development board utilized in the virtual laboratory.

MODELS, TEXTURES AND ANIMATION

The virtual laboratory project was developed using high end, 3D interactive animation development tools. Autodesk Maya software was utilized to model and texture the 3D laboratory components as polygonal surfaces and to animate their

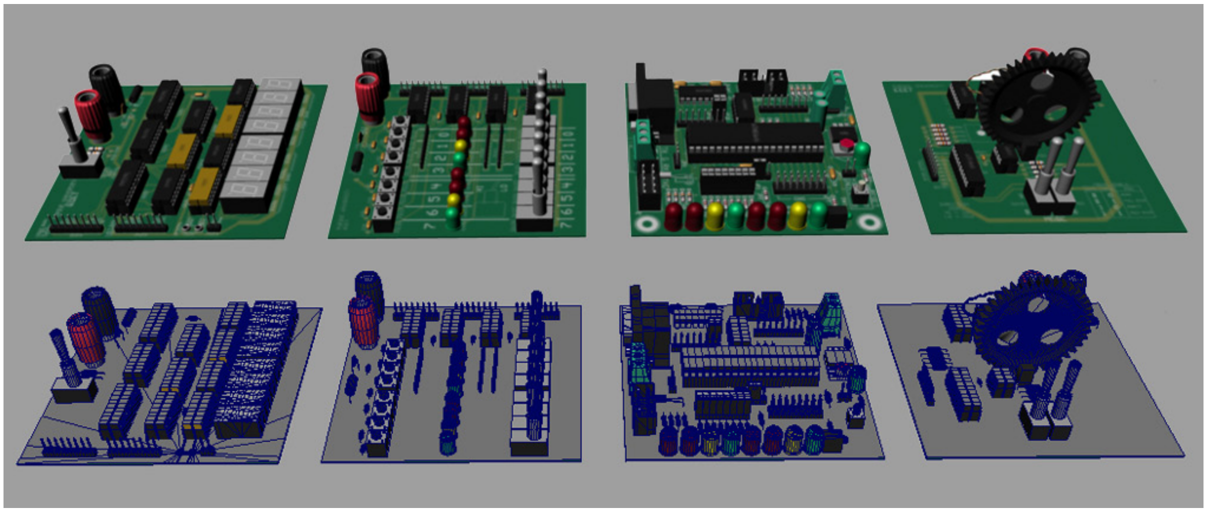

Figure 3 – Development Board Modeling

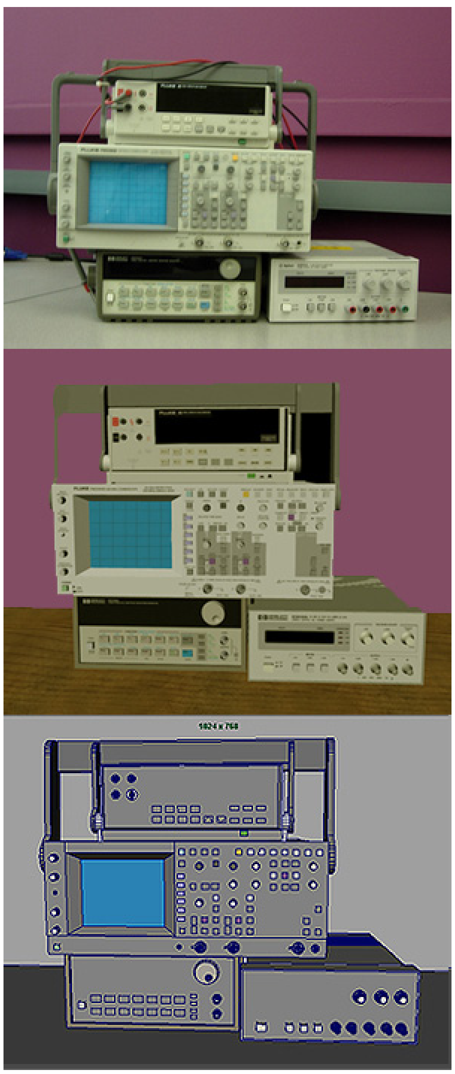

Figure 4 – Modeling of Test Equipment

functionality. The textures were created using photographs of the actual development boards. In order to achieve a high level of performance and speed in response to user inputs, the poly-count of each model was kept below 20,000 polygons. Color and bump maps were employed to simulate photorealistic details in order to maintain a high level of representational fidelity within the environment. Figure 3 and 4 illustrate the creation of the virtual devices within the environment. Once the models were created, they were exported as .obj files.

Interactivity with the 3D components was programmed with OpenGL and the C(++) programming language. In order to create a platform independent environment, the OpenGL Utility Toolkit (GLUT) was utilized to allow the application to be executed on platforms such as Linux, Macintosh OS, or Windows based systems. Each individual development board was treated as a separate graphics file with the movable parts exported separately in order to provide easy manipulation of the model within the OpenGL framework.

The virtual laboratory workspace is designed with a matrix setup where specific peripheral boards are always placed in the same quadrant of the workspace. This was initially done to simplify the creation of the interconnecting wires and cables required to perform a typical laboratory exercise. Students create wire connections between the virtual microcontroller board and the peripheral development boards by selecting the desired wire type from the setup pull-down menu as shown in figure 5. The environment has also been programmed with "hot keys" that allow the user to simply press a number between two and eight to place a multi-conductor cable between two of the development boards. A similar process is followed in order to create the power cable connections between the individual development boards and the virtual power supply.

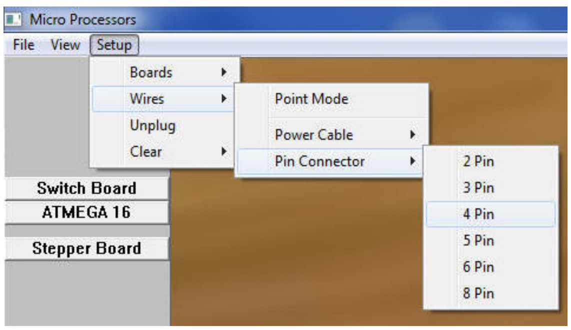

Figure 5 – Pull-Down Menu for Wire Placement

In all cases, the interconnecting cables and wires are created in a dynamic fashion. This allows wires and cables to be placed in any configuration required and can be manipulated by the user at will.

The wires and cables utilized in the virtual laboratory environment not only provide a visual representation of the connections within the environment, but they are also utilized to "carry" signals from one development board to the next. The interconnections of each development board are programmed using object-oriented techniques which allow the properties on one development board to be linked to the object associated with the opposite end of the cable. When a cable is placed in the system, as seen in figure 6, a logic value or voltage level can then be shared between two boards allowing values on toggle switches to be read by the virtual microcontroller and in a likewise fashion, an output value from the microcontroller can be utilized to create the appearance of turning lights on and off.

Picking methods enable the user to interact with switches, buttons and knobs on each of the

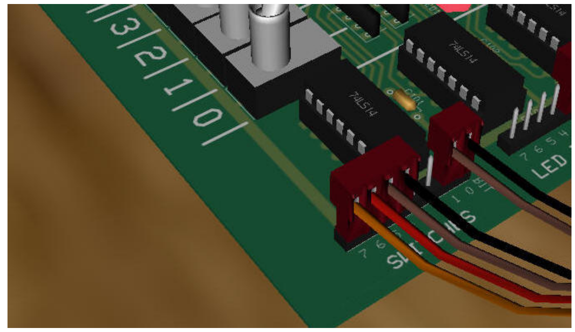

Figure 6 – Close-up View of Interconnecting Cables

objects in the virtual laboratory environment from any point of view. When a user selects a switch by clicking on it with the mouse, the switch will change positions. For instance, the shaft of a toggle switch will move from one position to the next as seen in figure 7. Likewise, pushbuttons will move up and down. Users can rotate knobs by clicking on the knob in the viewing window and by holding the right mouse button down, while dragging the mouse in the desired direction of rotation.

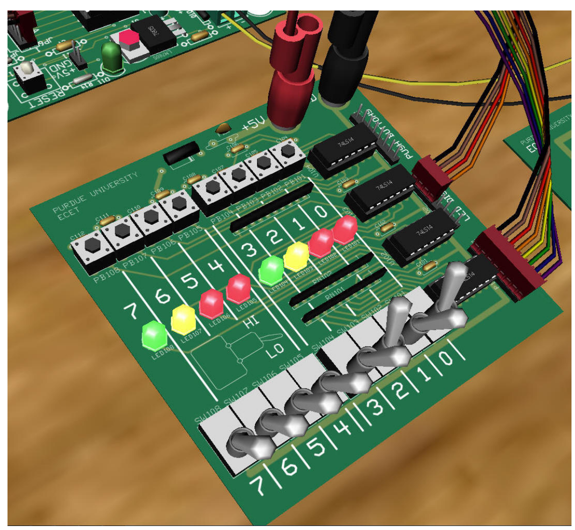

Figure 7 – Toggle Switch Movement

VIRTUAL CODE EXECUTION

The embedded microcontroller development board is based on the ATmega16 RISC microcontroller from Atmel Corporation. The virtual microcontroller supports FLASH, RAM, EEPROM, Register File, and Input/Output Register locations along with representations of the microcontroller's Status Register and Program Counter. The key feature of the virtual microcontroller board lies in its ability to decode and execute the various microcontroller instructions [1]. A unique feature of this environment is that the virtual microcontroller actually operates from an Intel Hex file. This feature eliminates the special files (normally object files) that are commonly used by commercial simulators [4]. The hex files can be produced by a variety of methods including any C compiler or assembler capable of generating executable code for the target microcontroller. Once selected, the actual file is loaded into the virtual microcontroller and then separated into the individual commands and any accompanying data required.

A system clock, based on the graphics update refresh rate, instructs the virtual microcontroller when to execute the next instruction. As each instruction is executed, various memory locations are read, data values are calculated, new values are stored, and the microcontroller's status register and program counter are updated as required to match the exact operation of a physical microcontroller. Depending on the instruction being executed, various flags in the status register can be utilized to control the branching or "jump" instructions within the microcontroller. The virtual microcontroller is capable of executing any of the assembly language instructions within the microcontroller which includes all the arithmetic & logic instructions, branch instructions, data transfer instructions, bit & bit-test instructions and MCU control instructions. There are four MCU control instructions that are not applicable to the virtual microcontroller laboratory environment and therefore have not been implemented. The remainder of the instructions from all the other categories have been successfully implemented and tested. Once the latest instruction has been completed, the virtual environment is updated so that output devices such as lights can be illuminated or turned off as required. In the event of a device like a stepper motor seen in figure 8, the instruction may result in the position of the gear to be rotated either clockwise or counter clockwise.

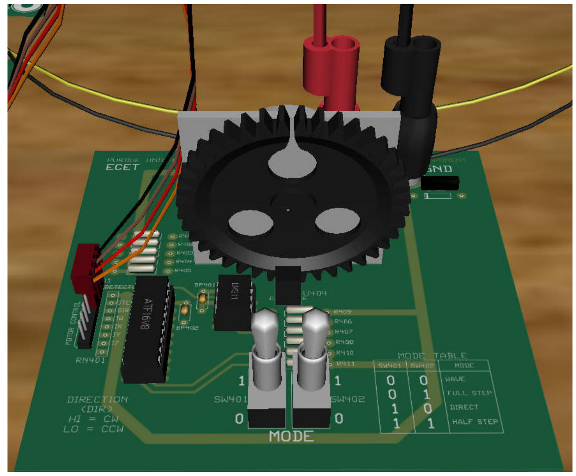

Figure 8 – Stepper Motor Gear

ENVIRONMENT DEVELOPMENT & LIMITATIONS

The virtual laboratory environment development plan was broken down into four main phases. The first phase was the creation of the microcontroller's basic operations. This phase required the modeling of the various memory locations within the microcontroller along with the instruction decoder and the status register as shown in figure 9 below. The advanced peripherals of the microcontroller were not required to prove initial operation and were therefore not modeled. The next phase of the development cycle was the creation of the 3D models for each of the peripheral boards re-

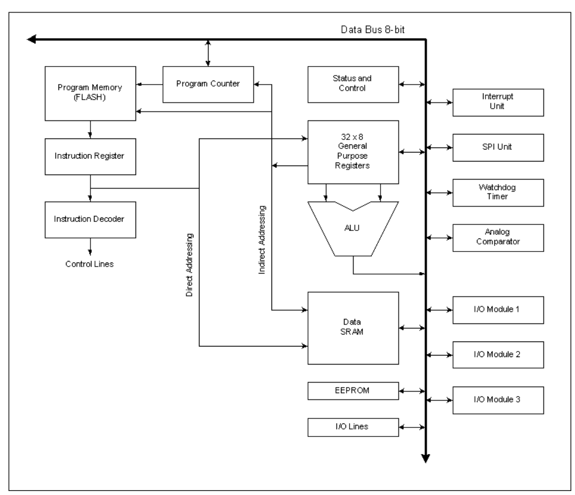

Figure 9 – Block Diagram of Microcontroller CPU

quired for the environment. The third phase of the development cycle was the linkage between the virtual microcontroller and the 3D models which included the animation of the moveable parts within the system. The completion of this phase allowed the virtual environment to be implemented and tested by the actual students enrolled in an introductory embedded microcontroller course. The last phase of this project, the completion of the advanced peripherals, has purposely yet to been completed. This limits the operation of the virtual laboratory environment to the first half of the introductory course.

EVALUATION OF USABILITY AND FUNCTIONALITY

Evaluation with experts

Initial testing was conducted by expert users consisting of faculty members and graduate students within the Electrical and Computer Engineering Technology department at Purdue University to ensure proper operation of the various features and functions of the environment. The initial evaluation included testing of normal operating parameters and extreme conditions. This testing was designed to determine the behavior of the virtual environment in the event a student user connects something improperly or inadvertently leaves a device unconnected. During these tests, cables were intentionally placed in the wrong location or improper orientation. In addition to incorrectly connected circuits, the testing focused on situations where the power supply was either not connected or set to an improper value. Thorough testing during the development cycle led to very few issues during the initial testing. The only major issue discovered was with respect to the operating voltages of the various peripheral boards due to miscommunication between the development team and was corrected prior to undergraduate student testing and validation.

Evaluation with students

Subjects: The entire sophomore embedded microcontroller class utilized the virtual environment to conduct a set of typical laboratory exercises. The pool of subjects included 42 students, 39 males, 3 females, with an average age of 20 years old.

Procedure

The laboratory instructor initially led the students through the preliminary stages of getting the environment setup and instructed the students on how to navigate through the virtual environment. Once the students were shown the basic requirements to navigate through the environment and make connections using the cables within the environment, the students were given a set of tasks to complete on their own.

Experiment 1: The first test required the students to verify and validate that the virtual lights and switches operated in the same manner as the physical lights and switches board. This particular experiment required the students to make virtual connections with cables to the virtual power supply and the lights and switches board. The students were required to manipulate the power supply output voltage and compare the results of the virtual environment again the physical hardware when in over-voltage, under-voltage, and appropriate voltage settings. The experiment also required the students to utilize the wire cable connection abilities within the virtual laboratory.

Results: At the completion of this exercise, the students recorded their results and answered questions related to virtual laboratory environment. The student results are shown in figures 10 through 16 below.

Overall, the students indicated that the virtual laboratory lights and switch operated in the same manner as the physical lights and switches board as seen in figure 10. The students also indicated that they were able to effectively utilize the virtual laboratory to install the required cables to complete the tasks as seen in figure 11. The students indicated some difficulty in utilizing and adjusting the output of the virtual power supply as shown in figure 12.

Experiment 2: After establishing that the virtual laboratory environment operated in a similar manner as the physical hardware, the next labora-

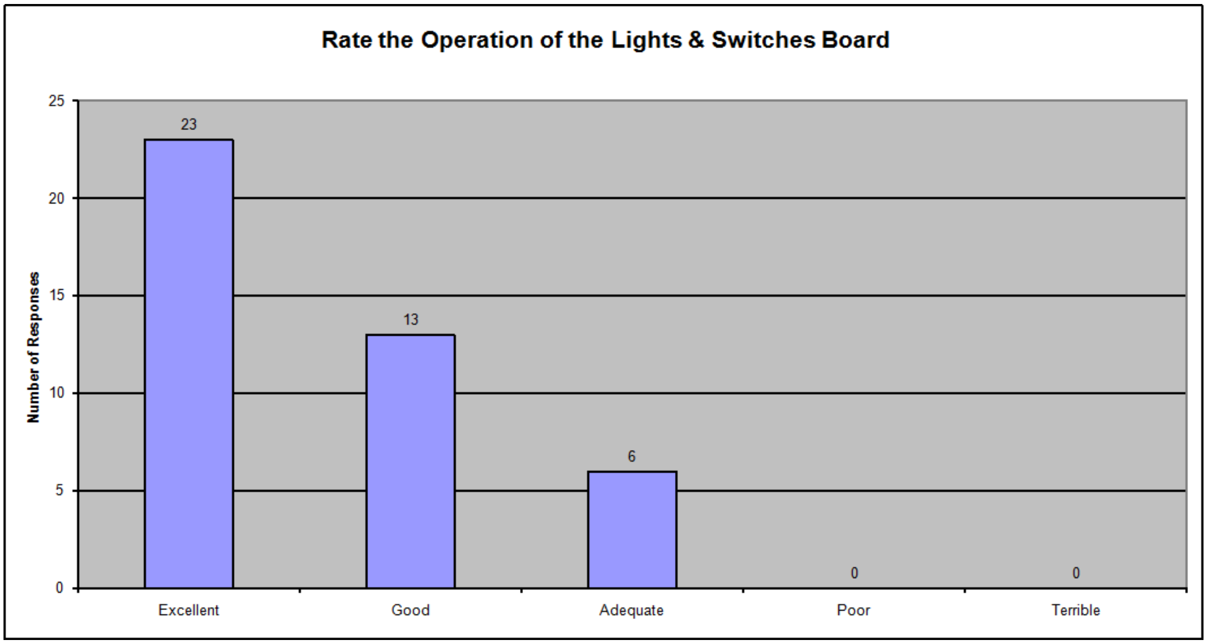

Figure 10 – Operation of the Lights and Switches Board

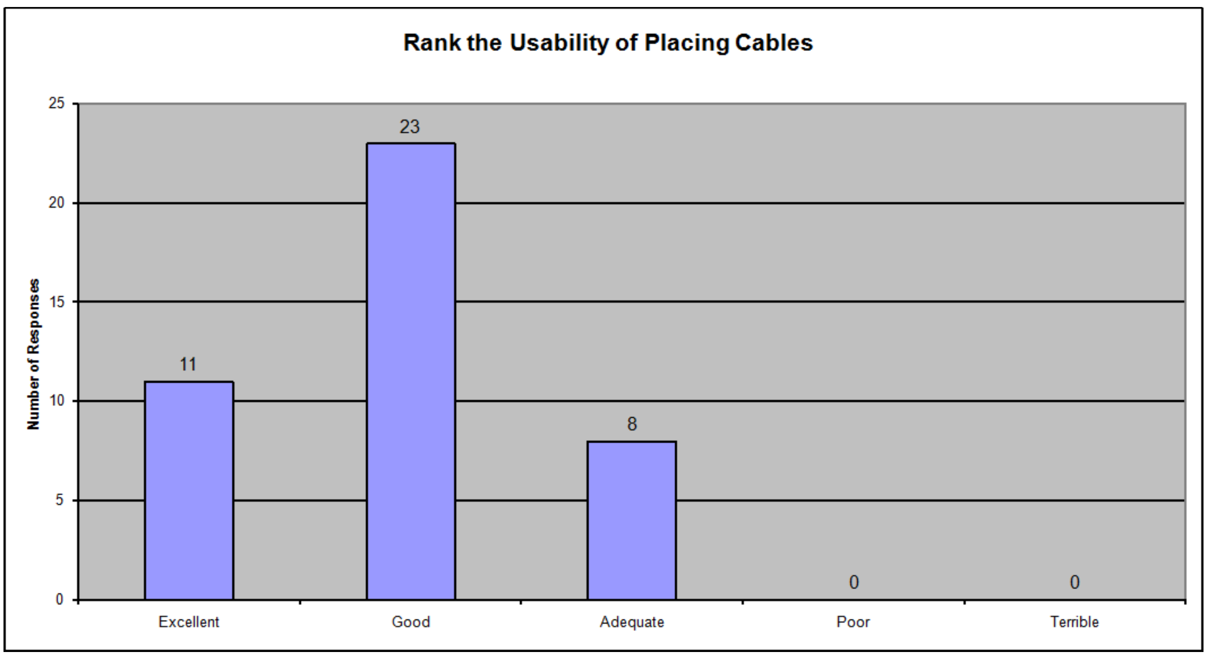

Figure 11 – Usability of Placing Cables

tory experiment required the students to actually create software and program the virtual embedded microcontroller. Since a typical first experiment with an embedded microcontroller requires the students to input and output data from the microcontroller, this approached was adopted for the virtual environment. The students were required to read values from the virtual toggle switches and display the values on the virtual LEDs. Since the students had previously performed the same procedure on the physical hardware, they were required to report their experiences with the virtual laboratory hardware against that of the physical hardware as shown below.

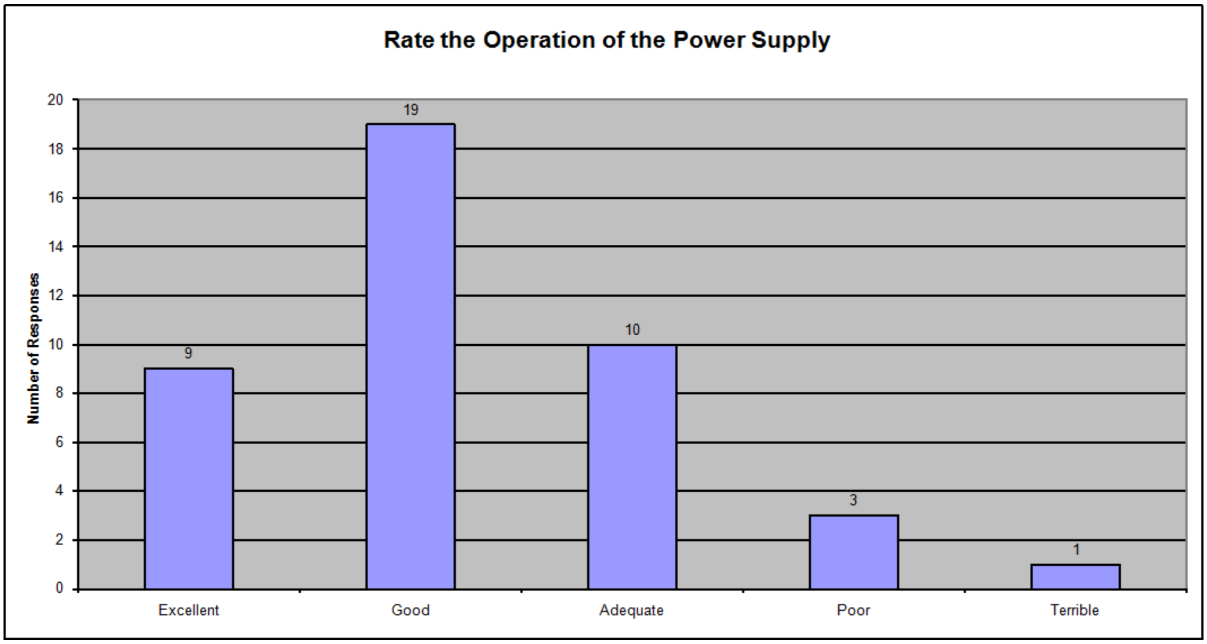

Figure 12 – Power Supply Operation

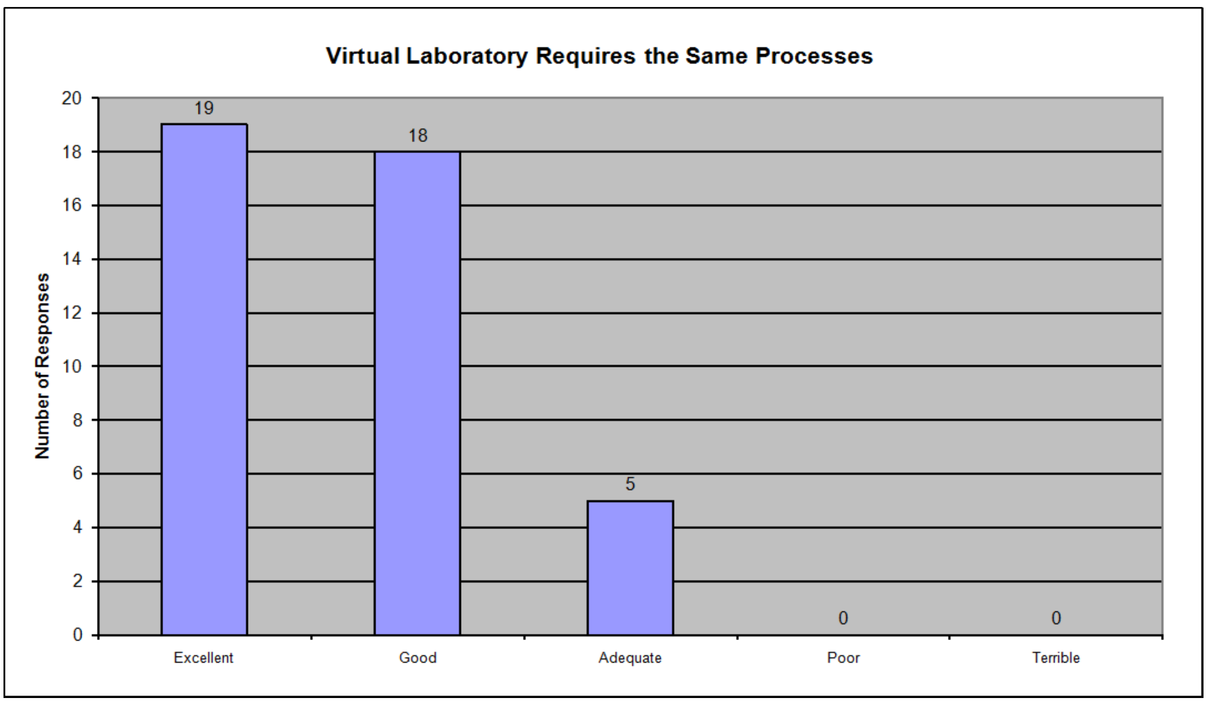

Figure 13 – Laboratory Processes

Results: The overall results indicate that the student users felt that the virtual environment required the same procedures and produced the same results as the physical hardware as seen in figures 13 and 14.

DISCUSSION

Overall, the students reported a very positive experience with the virtual environment. Two students within the course experienced difficulties above those encountered by the rest of the class.

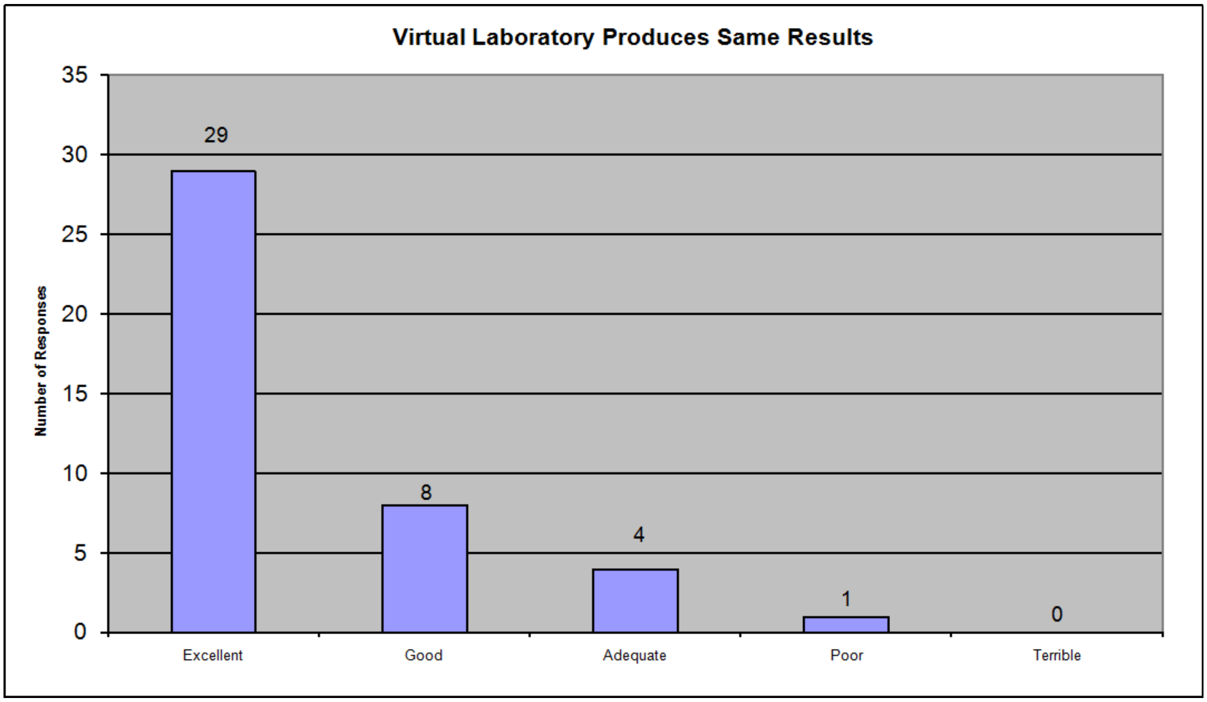

Figure 14 –Laboratory Results

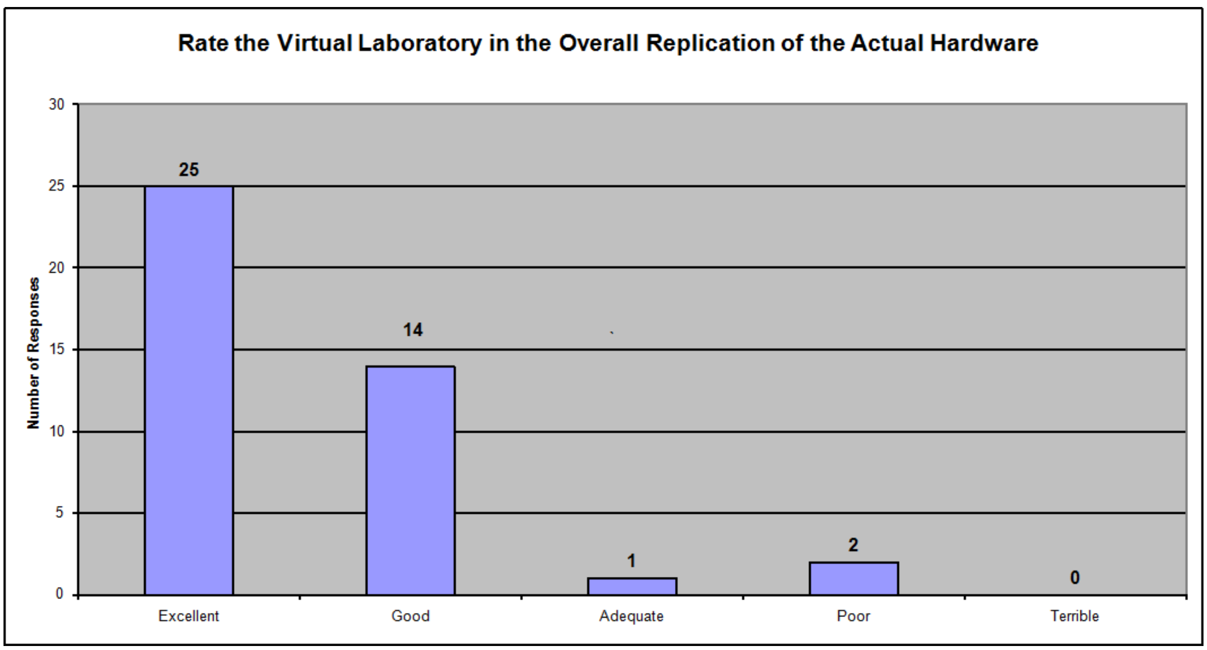

Figure 15 – Replication of Physical Hardware

The results of these two students are visible in the graphs of the data as shown in figures 14 and 15. Despite their difficulties, these students reviewed the VLE positively. Furthermore, the students involved with the validation of the virtual laboratory indicated a strong desire to be able to utilize the virtual laboratory from their residence.

The last question of the student questionnaire was designed to gauge whether or not the students

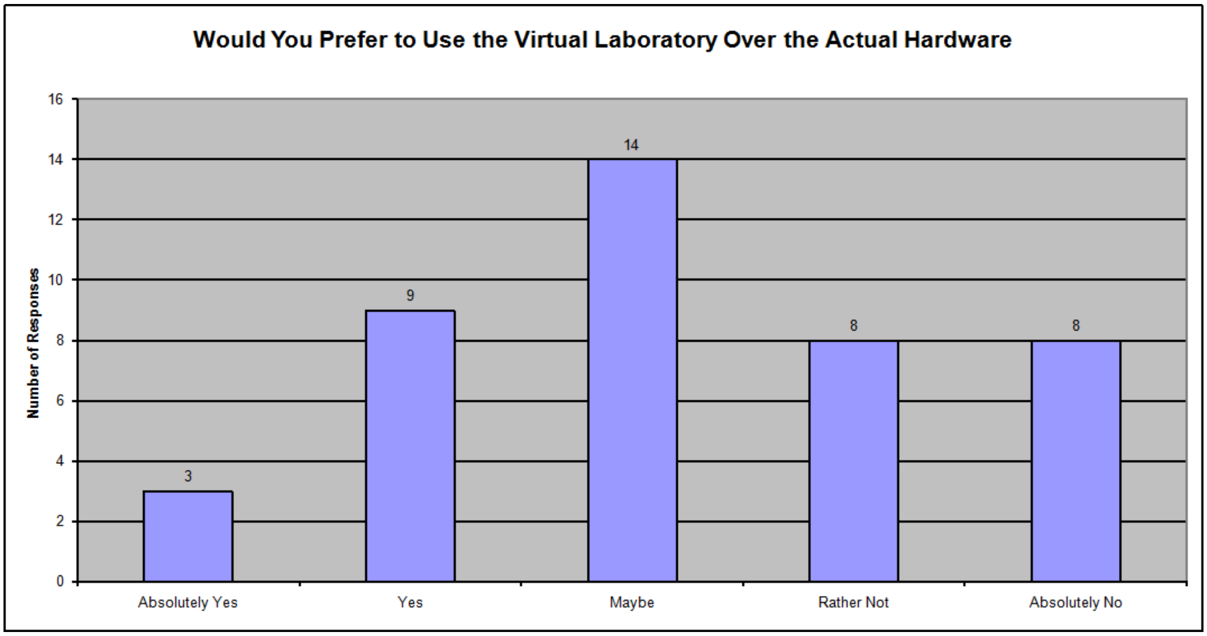

Figure 16 – Virtual Laboratory Preference

would prefer to utilize the virtual laboratory environment over the physical environment as seen in figure 16. The students who actively interact or play with newer video gaming systems indicated a stronger desire to utilize the virtual laboratory environment than the students that do not actively play with video gaming consoles.

Demonstration videos are available on-line at: http://www2.tech.purdue.edu/cgt/Facstaff/nadamovillani/microcontroller.htm

Future Work

The current virtual environment allows the students to perform all the activities associated with the first half of the introductory course. Future work will focus on expanding the content of the Virtual Laboratory to allow the students to perform advanced timer operations, advanced serial, and analog to digital conversions. Functionality will also be added to allow the saving of configuration files to allow assignments and configurations to be submitted electronically for instructor help or to verify assignment completion. This feature will allow students to perform laboratory activities from distance.

Once the advanced peripheral functionality has been added, additional work will be undertaken to expand the interface of the virtual laboratory environment to facilitate students with both visual and/or physical limitations. Many laboratory assignments require a high-level of dexterity and good vision [1]. According to Duarte and Butz, students with reduced motor skills can at most, watch their laboratory partners perform the experiments [5]. In 1999, the U.S. Department of Education's National Center for Education Statistics (NCES) reported that an estimated 428,280 students with disabilities were enrolled at two-year and four-year postsecondary educational institutions. According to a recent search of the Purdue University Office of the Dean of Students database, over 400 students could benefit from a system that addresses impairments. The VLE will be designed to meet the needs of these students. It will be designed according to the policy of the U.S. Department of Education - National Institute on Disability and Rehabilitation Research (NIDRR 2007), and the Accessible Digital Media Guidelines established by the National Center for Accessible Media (NCAM 2009). Specifically we will consider guidelines A (images), E (interactivity), F (graphs), G (math), H (multimedia). In addition, the software will support specialized input devices in order to meet the needs of students with limited dexterity.

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