Undergraduate Training to Teach a Hands-on, Problem-based, Novel Application of Embedded Technology in K-12 Classrooms

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Principles of K-12 Engineering Education and Practice

Abstract

An internally-funded undergraduate research project proposes to study the effectiveness of a hands-on, problem-based science, technology, engineering, and mathematics (STEM) course for three levels of public education: elementary, middle, and high school. The project will have nine undergraduate students from Embry-Riddle Aeronautical University led by a graduate student, undergraduate technical lead, Embry-Riddle Aeronautical University alumnus, and advised by an Embry-Riddle Aeronautical University faculty member, assume the role of K-12 teachers. Undergraduate participants will instruct public school students in state-of-the-art embedded technologies involving micro-electronics prototyping, an electronics hardware and software class under development by Prometheus Education, Inc. The undergraduate research project will take place over the course of the 2013-14 academic year, where student-teachers will master material and develop lesson plans suited for the three K-12 cohorts in the first semester, then assume the role of STEM teachers for the three K-12 cohorts in the second semester, and perform literature-based research and field data collection research duties throughout the academic year with the ultimate goal of dissemination of findings to national STEM education conferences.

During the first semester, the student-teachers will use the adult-learner oriented lesson plan and electronics kit provided by Prometheus Education, Inc. to create new lesson plans appropriate for all three levels of public education. While learning and developing materials, undergraduate student-teachers will participate in pre- and post-assessment to garner gains in technical aspects of the curriculum and in teaching/learning practices, curriculum design, and educational research. Undergraduate participants in the first semester will review engineering education conference papers and journal articles through a formalized process. Undergraduate research participants will research the writing of appropriate learning objectives / desired outcomes to STEM students of varying stages in their K-12 education. Student-teacher-researchers will develop outcomes-based, level-appropriate lesson plans and assessment materials.

The purpose of this first phase of the study is to gauge the impacts on undergraduate STEM student-teacher-researchers of a series of four-hour Saturday-based sessions occurring over the course of Fall Semester 2013. Participants in this first phase of the internally-funded undergraduate research project will be assessed for their gains in the areas of K-12 STEM teaching, learning, and educational scholarship, as well as their mastery of relevant technical content necessary for successful micro-controller design, build, application, and instruction to others.

Second phase findings from actual lesson plan application in the three K-12 classroom cohorts will be presented in later dissemination efforts, however a preview of preliminary results will be presented along with complete Phase 1 findings.

Introduction

Science, technology, engineering, and mathematics (STEM) K-12 outreach serves to increase the exposure, awareness, and literacy of K-12 students towards the STEM fields, and increase the preparedness, quantity, and diversity of the ranks of students pursuing STEM both academically and eventually professionally. Student exposure and experience at the K-12 levels with relevant, modern technology can promote student pathways to STEM academic and professional careers. However, there is an ever growing gap between what public school teachers can teach, and what is becoming available in the world in terms of technology. With their heavy responsibilities, it is extremely difficult for teachers to find time to learn all available new skills, or seek new technology that could be vital in the classroom. Student interest in the STEM fields is also slipping, and college attrition rates in the STEM fields are incredibly high,[1] especially among low income, or minority students.[2,3] Resources on new technology that can be adapted to the classroom are often disparate and incomplete, leaving teachers with massive learning curves to overcome before they can successfully incorporate the new technology. STEM, and especially technology classes are in dire need of development and research to help put new technology into the curriculum.[4]

Purpose

This project proposes to bring new technologies to public schools by having undergraduate students from Embry-Riddle Aeronautical University assume the role of student, teacher and researcher with the mission of adapting the Prometheus Education, Inc. Micro-Electronics Prototyping and Software (MEPS) course for different age groups. The student-teachers will adapt lesson plans for all three levels of public school: Elementary, Middle, and High School. The purpose of this first of three phases of the study is to gauge the impacts on undergraduate STEM student-teacher-researchers of a series of four-hour Saturday-based sessions occurring over the course of Fall Semester 2013. Participants in this first phase of the internally-funded undergraduate research project will be assessed for their gains in the areas of K-12 STEM teaching, learning, and educational scholarship, as well as student-teacher mastery of relevant technical content necessary for successful micro-controller design, build, application, and instruction to others.

Embedded technology micro-controller programming topic areas, teaching/learning/research areas addressed in participant learning objectives / desired outcomes and assessment materials are enumerated in Table 1.

At the conclusion of corresponding Phases (1, 2, or 3) during which relevant teaching, learning, and implementation is carried out by student-teacher participants, participants will demonstrate an ability to describe, apply, and incorporate into K-12 lesson plans concepts of the topics listed in Table 1.

Table 1: Micro-controller prototyping and teaching, learning, research assessment areas.

Micro-controller Technical Topics	Teaching, Learning, Research Topics
• Digital Input and Output	• Writing Learning Objectives / Desired Outcomes
• Analog vs. Digital Signals	• Outcomes-based Curriculum and Instruction
• Voltage, Current, and Power	• Outcomes-based Assessment
• Diodes, Resistors, and Capacitors	• Active Learning Methods
• Pulse Width Modulation and Power Control	• Literature Searching / Reviewing
• Serial Communication	• Scholarship of Teaching and Learning Paper Components
• Software programming	• Institutional Review
• Digital Logic	

Background

The ideal technology for the classrooms is: inexpensive, easy to implement, challenging, and relevant.[4] One such technology that easily meets these criteria is microcontroller programming class in the C language. Microcontrollers are small, simplified computers. Microcontrollers are also ubiquitous, fast becoming embedded in almost every electronic device. For this reason, a student would be hard pressed not to see the immediate and overwhelming relevance of these devices. They come in an integrated circuit package, which makes them very robust and compact. Due to its ability to be programmed, a microcontroller is very versatile, allowing a developer to program it in a myriad of different ways. This versatility allows it to be used in many applications, giving the student a creative challenge, as well as technical one. Furthermore, a microcontroller is often very cheap, many can be purchased for less than $2.00 per unit, allowing a teacher to send the student home with finished projects as a souvenir after the class. For all of these reasons mentioned above, a microcontroller makes an ideal tool for use in the classroom; their versatility and cost mean that students could afford to create a diverse number of projects on a shoe-string budget.

Common microcontrollers are capable of a number of different functions. These functions often include digital signals, analog signals, or interface signals. A digital signal can be sourced by a microcontroller to drive a circuit, or sampled to read the state of a switch or button. Analog signals can also be sampled, often being sourced from a sensor or transducer, effectively allowing the microcontroller to take measurements of the world around it. Finally, a microcontroller can source or sample interface signals, which allow the circuit to exchange complex digital data, whether with a computer or other integrated circuit. Commonly, microcontrollers have memory management functions, timers, and interrupt vectors to add to the potential complexity of its programming. All of these functions serve as building blocks for basic electronic control and internal computation. In effect, a microcontroller is a small embedded computer which students can use. Since the device is programmed and controlled using the very low-level programming, a microcontroller is a particularly versatile device with great potential.

The MEPS course teaches the basics of microcontroller programming, assuming that the user has no prior experience with electronics or programming. The course could be suited for public school classrooms, and could work as a springboard to deeper, more challenging coursework. The MEPS course emphasizes tangible results with even pacing, ensuring that the student is given feedback from the circuit throughout a lesson. The MEPS course uses some simplifications to ease the student in, while still building the fundamentals until those simplifications can be done away with. Since the micro-controller is effectively a hardware chip that is software programmable, the course familiarizes the student with the dichotomy of hardware and software in design. The student physically builds electrical circuits on a breadboard, but the microcontroller itself is programmed by the student, and will interact with these other electronic components. The combination of software and hardware lends itself to teams of at least two students, and can appeal to both tactile and visual learners.

The hardware may consist of simple diodes, resistors, capacitors, and switches to more complex devices such as proximity sensors, temperature sensors, to full breadboard pluggable circuit boards. All of these sensors and parts are building blocks for greater projects. Projects can become more and more complex as the students learns how these components interact. The MEPS kit contains the parts necessary to instill the concepts of:

- Analog vs. Digital Signals
- Voltage, Current, and Power in Electrical Circuits
- Diodes, Resistors, and Capacitors
- Power Control
- Communication
- Software programming

The MEPS kit can be compared to other microcontroller based learning kits, such as the Board of Education and the Arduino. The MEPS kit was chosen for this project for a number of reasons. The first reason for selection is that the MEPS kit uses a standard solderless breadboard, which allows students to familiarize themselves with more industry standard tools. For instance, a student can decide to develop a project on light sensing applications, then find a light sensing component, and then integrate that component with their project, all without having to depend on one particular distributor, such as Arduino. The second reason that the MEPS kit was chosen was for its highly expansive nature. The MEPS kit allows students to go through the experience of looking through datasheets, performing trade studies on components, and then purchasing and integrating components. For any project, a student may be working with a component that no other MEPS student has worked with before. The third and final reason the MEPS kit was used because the MEPS software and hardware is a segue to other industry tools. The MEPS kit walks the student through the full experience of working with a microcontroller, without any oversimplification that would prevent a student from moving on to other platforms. To build a microcontroller based project a student must learn: electrical prototyping, digital logic, the basics of registers, and the basics of C programming. Since the MEPS platform builds the students' skills in all of these areas, it makes an effective learning tool for further learning, with or without a traditional instructor.

The microcontroller used in the MEPS course (see Figure 1) is a common model, and is representative of the basic functions of an embedded computer, while not being too expensive for classroom use. The microcontroller is capable of: basic digital input and output, analog to

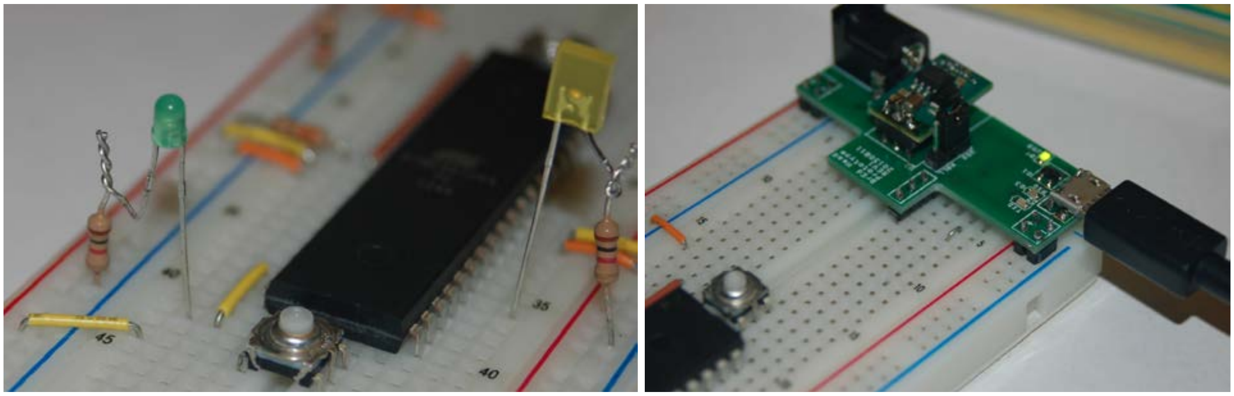


Figure 1. Microcontroller with surrounding components on breadboard (left) and breadhead (right) with connections.

digital conversions, serial communication, and pulse width modulation. The pulse width modulation and digital output allow the microcontroller to have a tangible interaction with the student, which is essential for younger students. The digital output functions can be used to toggle LEDs on and off, or drive an electronic relay. Pulse width modulation can be used for a number of applications, including motor driving or sound generation. Serial communication allows the student to communicate with a microcontroller using a computer. Sampling an analog signal and converting it to a digital signal allows the microcontroller to read data from many sensors, which is essential for automation, robotics, or scientific instruments. All of these functions can be leveraged by a student, and the programmed into the embedded computer so that the program is tangible, and automated.

Phase 1: Learning and Planning Procedure

The student Principal Investigator (PI), Co-PI, and Faculty Advisor recruited nine student participants. Student participants and student leadership were offered up to three credits of EGR 399, a special topics course for group or individual studies in exchange for their efforts. Grades were based on participation and attendance, lesson plan preparation, and K-12 STEM outreach conference paper and journal article reviews, of which each student was responsible for four two-paged reviews on preformatted forms, two conference paper reviews and two journal article reviews.

The university alumnus Prometheus Education, Inc. President prepared instructional materials, session procedures, and MEPS kits shown in Figure 2, with expenses reimbursed through the $5000 in undergraduate research internal grant funds. The lessons and procedures were geared towards a non-expert post-secondary level. Student-teachers met on Saturdays during the semester for four hours per session to cover the topics listed in Table 1. After each session the nine student teachers, in three teams of three with one delegate (team leader and coordinator) per team, met separately to write objectives-based, hands-on, problem-based lesson plans for their individually assigned cohorts of elementary, middle, or high school-level students. These lesson plans were then reviewed by experienced project leadership for technical quality, addressing learning objectives, and intended audience.

Figure 2. University-branded MEPS project kit.

Delegates regularly met, together with student project leadership and the Prometheus Education, Inc. President, to discuss issues in quality of lesson plans, technical issues, and the feasibility of learning objectives for the respective cohorts, given action words and the level of conceptualization expected per Bloom's Taxonomy-related materials. Student-teacher mastery of the material was expected to develop through the course of the four-hour weekly sessions (typical setting shown in Figure 3) on each topic, the discussions within the groups of three and subsequent cohort-specific lesson planning, discussions with student project leadership, and final adjustments and edits to lesson plans. In addition, subsequent lessons build on previous lessons, providing further conceptual reinforcement. At the conclusion of the semester, lesson plans were reviewed by teachers of the STEM outreach cohorts, with one teacher reviewing elementary and middle school-targeted lesson plans and a Project Lead The Way certified teacher reviewing the high school-targeted lesson plans and providing feedback.

Student-teachers and student leadership were given pre- and post-assessments at the beginning and end of the Fall 2013 semester, respectively, to gauge gains in MEPS technical areas, as well as high level and introductory teaching-learning-educational research topics. Students also individually reviewed two K-12 STEM outreach-related conference papers and two similarly-themed journal articles of their choice from a selection of over 40 articles provided by the faculty advisor, with multiple student-teacher reviews of each article permitted. These article reviews provided students with exposure to STEM education literature, a basis for lesson plan and activities designs, to springboard new ideas, and for literature reviews in their own

Figure 3. Weekly Fall Semester student-teacher content mastery and lesson planning sessions.

dissemination. Late in the semester students prepared and conducted poster presentations to the university Board of Trustees, which originally approved the internal undergraduate research grant program, as well as to the College of Engineering Advisory Board, comprised of accomplished alumni, experts, and members of industry. The representation the student-teachers provided of their efforts was very well-received.

All documents, whether for reference or submission, were made accessible by project personnel on a commonly-accessible Google Drive. This drive contained articles, technical references, lesson plans, poster designs, troubleshooting, presentations, schedules, pre- and post-assessments, learning objectives authoring resources, conference paper and journal article reviews referenced for lesson plan design, instrument design, dissemination, literature reviews, etc.

Phase 2: Teaching and Data Collection Procedure

Phase 2 of the project involves student-teachers teaching and gathering assessment data through participant-designed instruments. The three student-teacher teams will visit their respective cohorts while supervised by an on-duty teacher at their schools and facilitate the hands-on, problem-based (rather than just a rigid sequence of steps with a foregone conclusion) activities of the lesson plans, with a final working product at the conclusion of the semester. In this sense, the experience is also a scaffolded, project-based approach. Student-teachers will administer pre- and post-lesson assessments, pending Institutional Review Board and parental approval, and collect data for later analysis. At the conclusion, students will have a completed, working project. Data collected will include pre- and post-assessments, student survey feedback on instructional materials and learning activities, and teacher feedback and suggestions.

Phase 3: Data Analysis, Reporting, and Dissemination Procedure

In the final phase of the internally-funded, undergraduate educational research project, student-teachers will analyze assessment data and report findings in a final report required per the internal undergraduate research grant program requirements. Students will also disseminate findings to national journals and regional undergraduate research forums.

Undergraduate Student-Teacher Review of K-12 STEM Outreach Literature

The importance of exposing K-12 students to STEM through outreach from post-secondary personnel (faculty, staff, and students) is illustrated throughout numerous documented projects and studies, where impacts on student literacy, awareness, interest, self-efficacy and attitudes towards STEM disciplines are shown. The range of project contexts is understandably broad, however many projects employing contexts related to electronics, microcontrollers, and robotics can be found with encouraging results. Many of these instructional interventions are problem- and/or project-based, hands-on, active, and can allow K-12 students to relate to experiences and contexts with which they are familiar. Embry-Riddle student-teachers on this project reviewed the articles below to gain insight on successful and impactful K-12 STEM outreach programs and to determine prescriptions to apply to their own project.

Student-teachers reviewed Chubin, May, and Babco's report[5] that the number of underrepresented minorities in higher education, particularly engineering, have been declining over the past years and that the best actions taken to improve the amount of underrepresented persons in the field include: after school programs, pre engineering curriculum, better admissions and marketing practices for college, and more promotions and recognition programs in industry.

The efforts at a Gannon University STEM outreach project involving sixty local students in grades 10 through 12 invited to campus on their ECE Day were also reviewed. These efforts to integrate K-12 STEM learning using electrical engineering disciplines at schools providing higher education encouraged high school students to pursue degrees in STEM-based fields at university levels. The authors tried to accomplish that by providing the students early knowledge on subjects related to STEM and hence help them with admission into universities. Students in this study were able to better understand the STEM concepts and use them in the project activities and students showed an ability to use STEM concepts to solve real world engineering problems.[6]

Student-teachers reviewed a Clarkson University science and engineering camp with a goal of creating a unique environment for students between the grades of 7 and 12 to provide opportunities for students from economically disadvantaged, rural areas to realize their potential for college entry as STEM majors and careers. The camp was based around creating a functional rollercoaster that would then be simulated on a computer after their design had been completed. The camp also provided a simulated form of "roller coaster design companies." The impacts of the camp were then discussed with the students to find its successfulness. A basic assessment in student math and science capabilities was conducted to establish student abilities. There was a stated progress in students from a year to year basis in their proposed self confidence in mathematics and science[7] as gauged by student surveys.

In another university K-12 STEM outreach effort reviewed, a partnership was created between the University of Colorado Boulder's Engineering Engineering Education initiative and St. Vrain Valley's School District to create a replicable pre-college engineering program. Through this program data have shown to positively impact students in the K-12 range in fields such as preparedness, and persistence in engineering experiences[8]. The goal of the project was to provide the students with the knowledge and experience to be successful in their first year of college. This study featured a continuous collection of evaluations with quantitative and qualitative methods used to measure the success in each student. Quantitative methods included attitudinal surveys, academy application analyses, demographic data, and student attendance and retention comparisons. Qualitative methods included open-ended survey questions for students, small focus groups for students, and weekly discussions with teachers.

Student-teachers also noted that when urban south Michigan and large suburban northern Indiana elementary students were asked to draw their perception of an engineer, and then asked questions regarding the drawings such as gender, students were depicting an engineer is a mechanic laborer and a technician[9]. Students also listed many possible jobs of engineers that included fixing or building vehicles, engines, and different tools. More than half of the students said that their engineer was a male.

In yet another paper garnering student-teacher interest, student-teachers noted that males and females both experienced an increase in motivation towards STEM areas[10] in a 4-H faculty-developed robotics program teaching 4-H clubs and afterschool programs STEM concepts. Mainly targeted at middle school students, this program utilized robotics, GPS receivers, and geographic information system (GIS) software to teach through experimentation via lessons developed for middle school students to learn through experimentation the concepts of STEM through robotics, GPS, and GIS systems. The authors used an "enhanced" version of a 37 question, multiple choice assessment which covered "topics in computer programming, mathematics (including fractions and ratios), geospatial concepts (coordinate estimation based on location), engineering (such as gears and sensors), and robotics (such as looping and multi-tasking)." The same instrument was used for pre- and post-testing. The authors also utilized a 33 Likert scale item assessment developed by the project staff. It consisted of a section on motivation and another on the use of learning strategies.

An engineering camp in southern Texas sought to introduce underprivileged students with underrepresented ethnic backgrounds high school students to hands-on real world engineering problems, and in turn encourage them to pursue a degree in a STEM field. There were four three-hour long engineering projects that consisted of bridge building, computer technology and Bluetooth, river pollution, and wax 'o' mania. At the conclusion of the study, the authors received positive feedback from the participants and concluded from their responses on a final survey that they were more interested in STEM related fields than before the camp[11]. The purpose of the project was to increase the students' awareness of STEM, and especially, engineering fields. The researchers' main focus was to create a well-designed camp for these students that also increases their self-confidence towards engineering through hands-on projects and technical activities. The program was a week-long camp that consisted of 30 students that were selected by an application process which consisted of a point system based on their GPA, family income, and school attendance.

Student-teachers used the literature they reviewed, sampled above, and the lesson review feedback from the teachers of the three K-12 cohorts, as well as advice from their advisor and experienced graduate student lead to guide their lesson planning and assessment designs. The student-teachers reported they were encouraged and influenced by their reviews of literature; they saw similarities between past efforts and their own and used the contexts, formats, and instruments of the projects they reviewed to guide their own program design, lesson planning, learning activities, and impact assessment instruments.

Results

Student-teachers progressed from having little to no hands-on microcontroller hardware and software design and build experience (excluding two of the participants with some prior experience), to being able to build and program their own microcontrollers and design lessons for future mentees to follow. However, it is apparent that the student-teachers had a baseline understanding of microcontroller terminology and concepts, albeit with likely less ability to apply this knowledge in the absence of real implementation experience. Table 2 shows statistically insignificant pre- and post-test mean differences when student-teachers were assessed on basic terminology and high-level concepts in microcontroller competence. The authors assessed the students on this type of outcome rather than an ability to implement the microcontroller hardware and software in a real application. Based on observations and lesson plans and other deliverables, student-teachers did seem to make gains in the application of microcontroller hardware and software.

Table 2. Microcontroller terminology and concept pre- and post-assessment.

Technical Assessment

Student-Teacher	Pre-test	Post-test
1	12	15
2	21	21
3	19	18
4	16	16
5	18	19
6	19	17
7	17	23
8	19	19
9	18	19
Maximum Score	29	

t-Test: Paired Two Sample for Means

	Pre-test	*Post-test*
Mean	17.6667	18.5556
Variance	6.5	6.02778
Observations	9	9
Pearson Correlation	0.5525	
Hypothesized Mean Difference	0	
df	8	
t Stat	-1.12576	
P(T<=t) one-tail	0.14645	
t Critical one-tail	1.85955	
P(T<=t) two-tail	0.2929	
t Critical two-tail	2.306	

The maximum score of 29 is derived from the total possible number of correct single and multiple correct answer questions from this microcontroller technical assessment, where underlined answers are correct:

Microcontroller Assessment

1. What is the difference between an LED-Resistor pair with a higher resistance than another (assuming the exact same type of LED, and both resistances allow for the light to be visible)?

a) The higher resistance LED-Resistor pair is brighter
<u>b) The Lower resistance LED-Resistor pair is brighter</u>
c) Both pairs are at the same brightness
d) Not enough information to know

2. Let's say there is an LED and resistor pair connected into a +5V line and GND. What occurs if you remove the pair, and then put it in backwards?

<u>a) The LED will not emit light</u>
b) The LED will create a bright flash, and then extinguish
c) The LED will change colors and eventually extinguish
d) The LED will not light up, but will be broken and unusable

3. What is a register, in the context of microcontrollers?

a) a part of memory that is not necessary for microcontroller operation
b) a special portion of memory that identifies the microcontroller to other devices
c) an extremely reliable portion of memory than does not erase when the device is powered off
<u>d) a byte of RAM data that is tied to a physical function of the microcontroller</u>

4. How is FLASH different from RAM? [circle all that apply]

a) RAM is not able to hold on to data, even if it remains powered
<u>b) FLASH can only be written to a certain number of time before it is unusable, whereas RAM has infinite rewrite.</u>
c) FLASH does erase upon reboot, whereas RAM does not
d) FLASH is more compact, and can be packaged in a small card

5. What is the difference between volatile and non-volatile memory? (choose the best answer)

a) volatile memory is unreliable, and routinely carries faults
<u>b) non-volatile memory does not erase upon being powered down</u>
c) non-volatile memory is far more difficult to corrupt
d) volatile memory is liable to wipe itself at any moment

6. What is a digital signal?

<u>a) A signal that can be described by either a 1 or 0</u>
b) A signal that is only observable by a computer
c) A signal that must be decoded to be made useful
d) The only signal that can be used to make a computer

7. What is a serial signal?

a) A randomized signal
b) A signal that acts as a unique identifier for the device
c) A scrambled signal that interferes with other, useful signals
d) A signal that contains information that is delivered in a sequence

8. LEDs are... [circle all that apply]

a) Polar
b) dangerous
c) Semiconductors
d) Convert current to light

9. Which of the following is NOT proper programming practice?

a) Using lots of nested libraries to keep the main.c code clean
b) design code that is easy to modify in case there is a change in the project
c) save very version, and keep all changes, no matter how trivial
d) be easily readable to a reviewer who is not familiar with the program

10. The purpose of a flowchart in programming is to… (choose the best answer)

a) keep track of the data flow during a program's execution
b) Help the designer flow functions from one function to another
c) prevent data overflow on interfaces and memory devices
d) be able to design a program to follow a predictable, decision based behavior

11. USB Signals are… [circle all that apply]

a) Serial
b) Parallel
c) Encrypted
d) Receivable directly by an ATMEGA1284p microcontroller

12. To communicate between two UART capable devices Device 1 and Device 2 over serial you must…

a) Connect TX of D1 to RX of D2 and vise versa
b) Connect the TX of D1 to the TX of D2, and the RX of D1 to the RX of D2
c) Connect both devices to a central computer as a hub
d) Connect on device to another using a null modem

13. A Universal Asynchronous Receive Transmit (UART) signal is a simple digital signal, but it has the following format, in order (choose the best answer):

a) 1 start bit, 1 parity bit, 8 data bits, and 1 stop bit
b) 1 start bit, 8 data bits, 1 or 2 stop bits
c) 1 start bit, 5 to 9 data bits, 0 or 1 parity bit, 1 or 2 stop bits
d) 1 start bit, 5-8 data bits, 0 or 1 parity bit, 1 or 2 stop bits

14. A UART signal is transmitted to you with 1 parity bit, and 2 stop bits, and 6 bits of data, and is otherwise a standard UART signal. How much overhead does this signal have, where overhead is % of non-data bits to all bits sent?

a) 50%
b) 66%
c) 40%
d) 25%

15. What is a BAUD rate?

a) The inverse of the time period of one-bit of data on a serial stream
b) The rate of change of a digital system
c) How quickly a digital signal degrades over time
d) The CPU speed of an embedded microcontroller

16. A C-Program begins executing at what part of the code in the main.c file?

a) at the top of the code
b) at the start of the *main* function
c) at the beginning of the first included library
d) at the start of the *while()* loop

17. In the field of programming, and IDE program refers to what?

a) Integrated Development Environment
b) Internal Data Extraction
c) Interfaced Digital Electronics
d) Interfaced Design Environment

18. Instructions that computer hardware can understand and execute from are called:

a) source code
b) assembly code
c) pseudo-code
d) machine code

19. What is a compiler's role in software?

a) To gather code together to make proper documentation
b) To translate human readable code to machine executable code
c) To compile an analyze a software's performance
d) To error check a programmer's code

20. Which of the following are likely applications of microcontrollers?

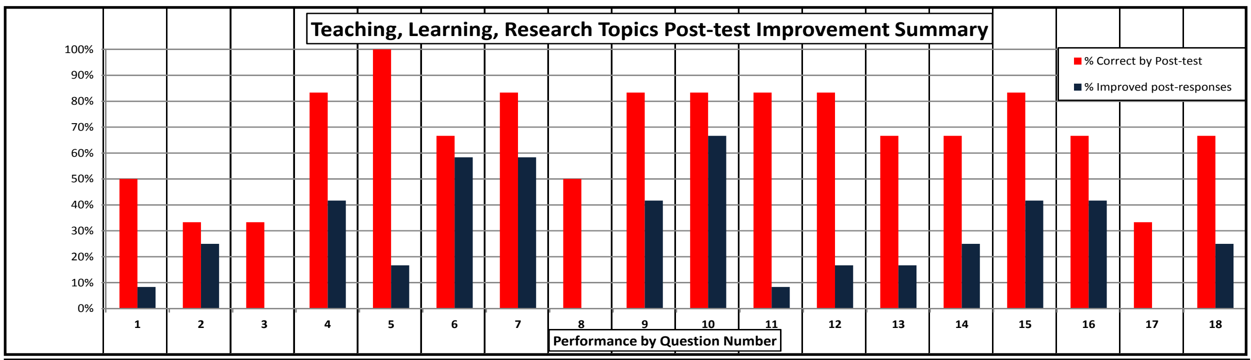
a) Smart Phone
b) Car safety system
c) Web-Support Computer
d) Portable encryption device

In the arena of teaching, learning, and educational research, student-teachers were asked to answer the following open-ended questions as pre- and post-tests. Student-teachers were only able to answer few of the following questions correctly in the pre-test:

1. Around what should student assessments, curriculum, and learning activities be designed?
2. What are common or typical components (or headings) found in scholarly articles?
3. What are typical or differences you observed between conference papers and journal articles?
4. What are <u>instruments</u> used for in educational research?
5. Describe what is wrong with this statement: "At the conclusion of the course, students will know/learn/understand blah blah blah."
6. What does IRB stand for and what is the purpose of IRB and/or why is it used?
7. If you are planning to conduct research on a new learning activity you are offering and wish to investigate similar applications' effectiveness and assessment approaches, describe what you can do.
8. How would you determine or find the parent or seminal article(s) for a particular area you are researching?
9. What is the problem with assessing students with a multiple choice test on terminology as a primary assessment tool after a nearly 100% hands-on, project-based learning activity?
10. To what does the level of complexity in the tasks represented by action verbs relate?
11. What is one way a curriculum designer can scale the learning expectations for students of different ages or levels studying the same topics?
12. What is an abstract and what should an abstract contain?
13. What is posed to help determine and state the purpose of a study?
14. Is it generally acceptable not to inform students of research involving them or their work? When is it somewhat acceptable or unacceptable?
15. What must you generally do with study participants before conducting research and what generally are their rights during research?
16. Why is educational research conducted? What is the scholarship of education or engineering education?
17. What should assessments of student learning assess?
18. What is(are) the pedagogical (instructional or learning) approach(es) we are using for our K-12 students in this project and why are we using this(these) approach(es), especially compared to "traditional" methods?

However, in the post-test all student-teachers were able to answer 10 or more questions acceptably. Figure 4 shows a summary of student-teacher demonstration of an ability to cogently discuss teaching, learning, and educational research topics by the conclusion of the post-test. Of student-teachers (n=6) who took both the pre-test and identical post-test at the beginning and end, respectively, of Fall Semester 2013, 80% were able to answer eight open-ended questions related to teaching, learning, and educational research satisfactorily during the post-test. Student-teachers were lowest performing in questions regarding scholarly article components and characteristics (questions 2 and 3) and in assessments based on student achievement of desired learning outcomes (question 17). Clearly, these areas require reinforcement. Regarding question 17, student-teachers had not yet developed assessments for the K-12 cohorts at the time of the post-test. Questions 2 and 3 involved no formal instruction regarding conference or journal paper and student-teachers answered those questions based prior experience, if any, and any observations made during their reviews of two conference papers and two journal articles each.

Some student-teachers were exposed to certain facets addressed in the instrument more as a result of the unique experiences from their project work such as scholarly articles reviewed, roles within their teams, discussions with the faculty advisor, etc. Most student-teachers were able to articulate the application of learning objectives, terminology such as instruments, why using the words learn/know/understand in learning objectives is discouraged and why the use of action



QUESTION TEXT:	Around what should student assessments, curriculum, and learning activities be designed?	What are common or typical components (or headings) found in scholarly articles?	What are typical or differences you observed between conference papers and journal articles?	What are INSTRUMENTS used for in educational research?	Describe what is wrong with this statement: "At the conclusion of the course, students will know/learn/understand blah blah blah."	What does IRB stand for and what is the purpose of IRB and/or why is it used?
Question Number	1	2	3	4	5	6
% Correct by Post-test	50%	33%	33%	83%	100%	67%
% Improved post-responses	8%	25%	0%	42%	17%	58%

QUESTION TEXT:	If you are planning to conduct research on new learning activity you are offering and wish to investigate similar applications' effectiveness and assessment approaches, describe what you can do.	How would you determine or find the parent of seminal article(s) for a particular area you are researching?	What is the problem with assessing students with a multiple choice test on terminology as a primary assessment tool after a nearly 100% hands-on, project-based learning activity?	To what does the level of complexity in the tasks represented by action verbs relate?	What is one way a curriculum designer can scale the learning expectations for students of different ages or levels studying the same topics?	What is an abstract and what should an abstract contain?
Question Number	7	8	9	10	11	12
% Correct by Post-test	83%	50%	83%	83%	83%	83%
% Improved post-responses	58%	0%	42%	67%	8%	17%

QUESTION TEXT:	What is posed to help determine and state the purpose of a study?	Is it generally acceptable not to inform students of research involving them or their work? When is it somewhat acceptable or unacceptable?	What must you generally do with study participants before conducting research and what generally are their rights during research?	Why is educational research conducted? What is the scholarship of education of engineering education?	What should assessments of student learning assess?	What is(are) the pedagogical (instructional or learning) approach(es) we are using for our K-12 students in this project and why are we using this(these) approach(es), especially compared to "traditional" methods?
Question Number	13	14	15	16	17	18
% Correct by Post-test	67%	67%	83%	67%	33%	67%
% Improved post-responses	17%	25%	42%	42%	0%	25%

Figure 4. Summary of student-teacher improvements by the teaching, learning, educational research post-test.

verbs allowing for measurable abilities is preferred, the importance of having assessment contexts and formatting match the learning activity contexts and formatting, changing action words within learning objectives to match different levels of advancement of students and distinct expectations of conceptualization, and generally correct conceptions of ethics in human subjects research and the role of the Institutional Review Board. In other areas of the surveys, student-teachers had varied results.

Discussion

Student-teachers involved in both technical training on MEPS and K-12 lesson plan writing can master technical material through the course of immersion in adult-targeted lesson plans (to be made available on the web – link here) and write K-12 level-specific objectives-based lesson plans employing problem-based, hands-on learning activities that may keep K-12 students engaged and adequately scaffolded through new material. The effectiveness of these lessons will be gauged during Phase 2 of the project through the collection of assessment data with the K-12 students in the subsequent semester. Lessons to K-12 cohorts and assessment data collection will commence as the final revision of this text is submitted. Further dissemination, particularly of Phase 2 findings showing K-12 student impacts in terms of attitudes, confidence, interest, and technical abilities are to be disseminated during Phase 3 over the Summer of 2014.

Student-teachers were not properly assessed on their abilities to perform hands-on microcontroller, so concrete evidence of student-teacher gains are only evident from observation of student progress in Saturday sessions and resultant deliverables such as lesson plans and functional microcontrollers. In future efforts, better coordination between the faculty advisor and MEPS developer would address this issue through a practicum-based assessment. The most important results to determine project success will be the gains of the three K-12 cohorts made as a consequence of project learning activities during the next phase of the project.

Conclusion

The results from this project will be used as a springboard for improved efforts in the future, as well as work as basis for more novel educational projects. Once the learning kits can be adapted to the age groups of the most interest for success in STEM fields to a functional degree, new work in novel ways to use the kits can be developed. The tutorials and projects that can stem from this kit and this project are far reaching.

Within a short time, the adapted tutorials may be modified to encourage critical thinking the integration of STEM subjects into wider lens. Integrated STEM[12] is the concept of putting STEM into a broader context for students. An example of a possible integrated STEM project would be a student challenge to develop solar powered robots, weather monitoring stations, or visual art. These projects teach students that STEM lessons can be applied to improve the world around them. If students can be challenged to apply STEM via imbedded technology applications in hands-on problems from a tutorial delivered by a teacher, resultant positive impacts in student attitudes, interest, and confidence can allow for the pursuit of pathways to STEM careers.

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References

1. Epstein J. (2010). Graduation Gaps for Science Majors. *INSIDE Higher Ed*. - February 17, 2010. - March 22, 2013. http://www.insidehighered.com/news/2010/02/17/stem.

2. Galloway, S. (2012). African American Women Making Race Work in Science, Technology, Engineering and Mathematics (STEM) [Dissertation]. Chapel Hill: University of North Carolina.

3. Wade, R. (2012). Feeling Different: An examination of underrepresented minority community college students' major persistence intentions through the lens of STEM identity [Dissertation]. Seattle: University of Washington.

4. Butler, D., & Sellbom, M. (2002). Barriers to Adopting Technology for Teaching and Learning. *Educause Quarterly*, 2.

5. Chubin, D. E., May, G. S., & Babco, E. L. (2005). Diversifying the Engineering Workforce. *Journal of Engineering Education*, *94* (1).

6. Sundaram, R. (2011). Set up and Delivery of Electrical and Computer Engineering Projects at Undergraduate Engineering Universities for Outreach and Partnership with K-12 STEM Schools. *41st ASEE/IEEE Frontiers in Education Conference,* F4D-1.

7. Wick, D. P., Ramsdell, M. W., Fowler, K., Turner, P., & Schalk, P. D. (2011). University Outreach in STEM Education through a Roller Coaster Science and Engineering Camp. *41st ASEE/IEEE Frontiers in Education Conference,* S3D.

8. Zarske, M. S., Yowell, J. L., Ringer, H. L., Sullivan, J. F., Quinones, P. A. (2012). The Skyline TEAMS Model: A Longitudinal Look at the Impacts of K-12 Engineering on Perception, Preparation and Persistence. *Advances in Engineering Education*, *3*, (2).

9. Capobianco, B. M., Diefes-Dux, H., Mena, I., & Weller, J. (2011). What is an Engineer? Implications of Elementary School Student Conceptions for Engineering Education. *Journal of Engineering Education*, *100*, (2).

10. Nugent, G., Barker, Grandgenett, N., & Adamchuk, V. (2009). The Use of Digital Manipulatives in K-12: Robotics, GPS/GIS and Programming. *39th ASEE/IEEE Frontiers in Education Conference*, M2H-1.

11. Yilmaz, M., Ren, J., Custer, S., & Coleman, J. (2010). Hands-on summer camp to attract K–12 students to engineering fields. *Education*, *IEEE Transactions on*, *53*(1), 144-151.

12. Sanders, M. (2009). Stem, stem education, stemmania. *The Technology Teacher*, *68*(4), 20-26.