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The TECHNOLOGY INTERFACE INTERNATIONAL JOURNAL (TIIJ) is an independent, not-for-profit publication, which aims to provide the engineering technology community with a resource and forum for scholarly expression and reflection. Articles appearing in TIIJ may represent research not requiring statistical analyses and which typically comes from educators wanting to discuss "best practices" activities in their classrooms, or from industry personnel wishing to publish innovative designs or novel applications from their businesses or organizations.

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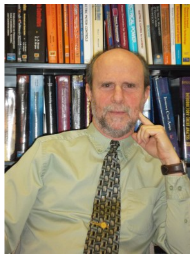
TABLE OF CONTENTS



EDITOR'S NOTE

Philip Weinsier, IJERI Manuscript Editor

The editors and staff at IAJC would like to thank you, our readers, for your continued support, and we look forward to seeing you at the upcoming IAJC conference. For this fifth IAJC conference, we will again be partnering with the International Society of Agile Manufacturing (ISAM). This event will be held at the new Embassy Suites hotel in Orlando, FL, November 6-8, 2016. The IAJC/ISAM Executive Board is pleased to invite faculty, students, researchers, engineers, and practitioners to present their latest accomplishments and innovations in all areas of engineering, engineering technology, math, science, and related technologies.

In additional to our strong institutional sponsorship, we are excited this year to announce that nine (9) high impact factor (IF) ISI journals asked to sponsor our conference as well, and wish to publish some of your best papers. But I would be remiss if I didn't take this opportunity to remind you of the excellent impact factors (Google Scholar method) for our own three journals. The International Journal of Modern Engineering (IJME) has a remarkable IF = 3.00. The International Journal of Engineering Research and Innovation (IJERI) has an IF = 1.58, which is noteworthy, as it is a relatively young journal, only in publication since 2009. And the Technology Interface International Journal (TIIJ) with an IF = 1.025. Any IF above 1.0 is considered high, based on the requirements of many top universities, and places the journals among an elite group.

Selected papers from the conference will be published in the three IAJC-owned journals and possibly the nine ISI journals. Oftentimes, these papers, along with manuscripts submitted at-large, are reviewed and published in less than half the time of other journals. Publishing guidelines are available at www.iajc.org, where you can read any of our previously published journal issues, as well as obtain information on chapters, membership, and benefits.

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Editorial Review Board Members

ALIGNMENT OF REGIONAL AND ABET ACCREDITATION EFFORTS: AN EFFICIENT APPROACH TO ASSESSMENT OF STUDENT LEARNING OUTCOMES

ASM Delowar Hossain, New York City College of Technology; Tammie Cumming, New York City College of Technology

Abstract

In this paper, the authors discuss the motivation behind, importance and need, and assessment of student learning outcomes. Emphasis was placed on the need for a conscious, proactive, well-designed and coordinated effort to converge various assessment activities to make the process streamlined, focused, and more meaningful. Also demonstrated is a pathway to assessment efficiency through alignment of regional accreditation standards with ABET accreditation criteria.

Introduction

Accreditation is a mechanism of external quality review that examines academic institutions and programs for quality assurance. It is a rigorous mechanism by which institutions of higher learning are evaluated and guarantees that an academic institution's programs are delivering results on par with standards set by the profession for which the program trains its students. In other words, it acknowledges that an institution's standards provide a platform common to other institutions of the same level for student admissions [1-4]. Accreditation is an affirmation that an institution properly trains its students to meet the expectations that the stakeholders have from their students.

With an accredited institution or program, a student has some form of guarantee of receiving a quality education and securing recognition by other institutions and by employers. In summary, accreditation facilitates quality assurance, governmental aid, employer confidence and mutual acceptance between institutions. The standards of accreditation are set by a peer review board of faculty members from various accredited institutions. In the U.S., the accrediting bodies review colleges and universities globally. They encompass numerous programs throughout a range of professions and specialties including engineering, medicine, law, business, nursing, journalism, etc. This process involves billions of dollars and millions of students in the U.S. [5]. Accreditation is regarded as a valid authority at all levels (federal and state). Federal student aid to the institution is conditional upon the accreditation status of the institution [1]. Accreditors have moved ahead merely from a mere glance towards what is happening in the institutions towards an effort to understand how student learning experience contributes to their professional field. Accrediting bodies can be divided into four categories, according to their scope:

1. Regional accreditors: Accredit public and private degree-granting institutions.
2. Program accreditors: Accredit specific programs (e.g., law and engineering).
3. National faith-related accreditors: Accredit religiously affiliated institutions.
4. National career-related accreditors: Accredit mainly for-profit, career-based, single-purpose institutions, both degree and non-degree.

Among these four types, the regional and the program accreditors are more common; this current study focused on these two types of accreditors. There is a fundamental difference between regional and program-level accreditation. Regional accreditation is an institutional process, meaning an entire institution is accredited. This gives credibility to the institution as a whole. There are six regions in the U.S. —each with a regional accrediting commission. Six of the commissions are recognized by the Council for Higher Education Accreditation (CHEA) [6] as follows (see also Figure 1):

1. Accrediting Commission for Community and Junior Colleges Western Association of Schools and Colleges (ACCJC-WASC) [7]
2. Higher Learning Commission (HLC) [8]
3. Middle States Commission on Higher Education (MSCHE) [9]
4. Southern Association of Colleges and Schools (SACS) [10]
5. New England Association of Schools and Colleges [11]
6. WASC Senior College and University Commission (WASC-SCUC) [12]

In contrast, program-level accreditation gives credibility to a specific program or discipline within an institution; it certifies that a specific program adequately prepares its students to meet the expectations of the profession for which they are being prepared. For instance, an engineering program must be on par with the standards set by the engineering profession (e.g., Accreditation Board for Engineering and Technology—ABET). Examples of other program accrediting bodies are AACSB (Association to Advance Collegiate Schools of Business) that accredits the College of Business and Economics, and APA (American Psychological Association) that accredits the Counseling Psychology and School Psychology programs in the College of Education. This study focused on ABET as an instance of program -level accreditation (within the context of technology education) and MSCHE as an instance of regional accreditation.

For accreditation to take place, there must be a demonstration of achievement of certain goal. This process requires a systematic understanding of the students learning via a process called assessment. Assessment is one or more processes that collect and prepare the appropriate data for purposes of examining the fulfillment of student outcomes. An effective assessment utilizes appropriate measures, whether direct, indirect, statistical or qualitative, to verify the attainment of student outcomes. Assessment leads to continuous improvement (CI), which is often the goal of accreditation. CI is the program's apparatus for assessing, evaluating, and implementing the required improvements consistent with its stated educational goals and student outcomes. Figure 2 shows the continuous improvement process. Accrediting bodies typically conform to a number of the guidelines set forth in the Council for Regional Accrediting Commissions' (C-RAC) Principles for Good Practices, whether at the institutional or program level, such as: 1) require learning outcomes to be stated, assessed, and used to guide institutional improvement, and 2) not be very prescriptive in terms of specific assessment practices or tools. [13, 14].

Typically, the accreditation process involves at least two fundamental elements or some variation of them:

1. Self-study report: Institutions and programs prepare a written summary of their performance according to the standards of the accrediting organization.
2. Campus visit: Accrediting organizations normally send a visiting team to review an institution or program.

There are a number of reasons that necessitate a systematic assessment of student learning. The stakeholders are demanding the demonstration of student learning outcome measurements [15], which is why ABET requires accredited programs to consult stakeholders in student learning outcome issues [16]. Furthermore, according to the National Institute for Learning Outcomes Assessment (NILOA), accreditation is among the most important reasons to assess student learning outcomes [17]. In agreement with NILOA, the Outcomes Assessment Accreditation Handbook states that one of the objectives of technology program accreditation is to measure student outcomes and utilize that infor-

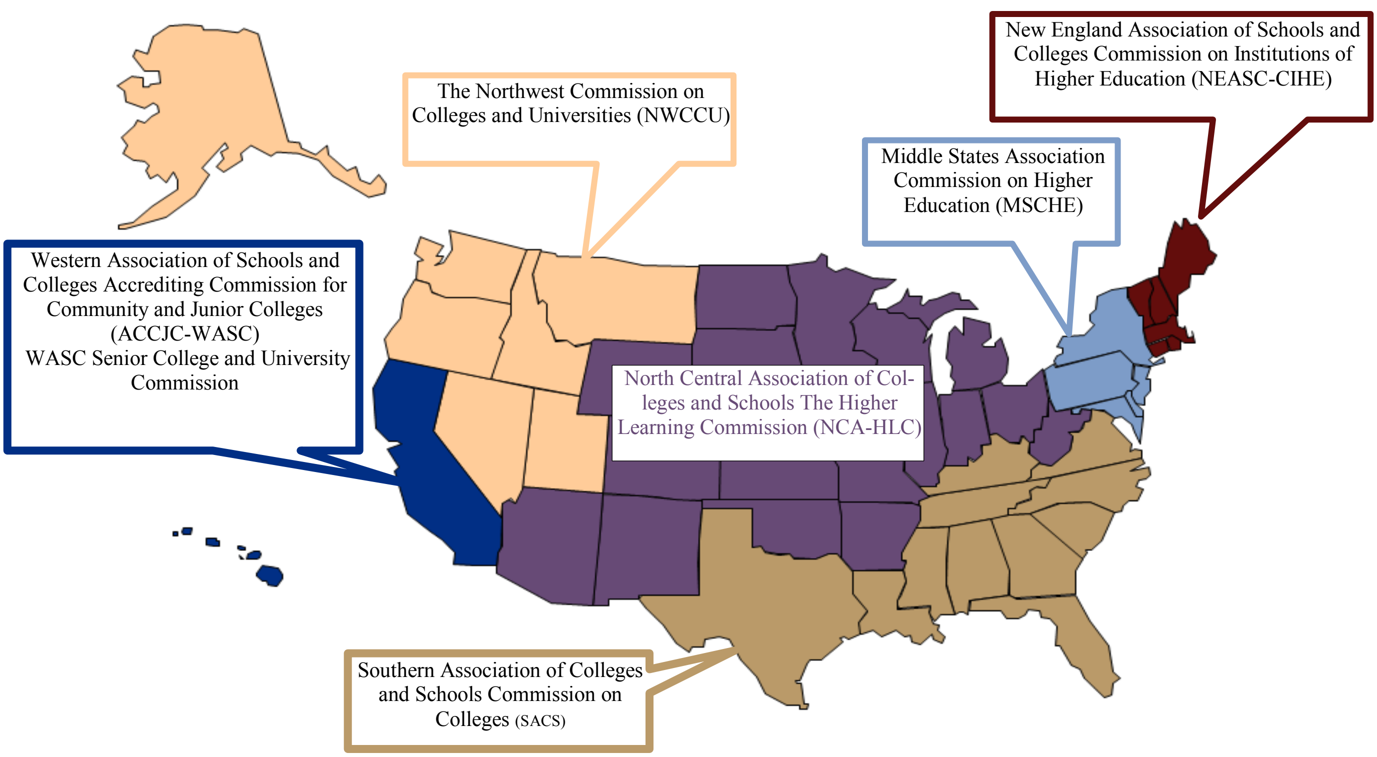

Figure 1. U.S. Regional Accrediting Bodies

mation to continuously improve programs [18]. MSCHE, for example, requires that the results of assessment be used to improve teaching and learning student outcomes [19]. This is also at the core of ABET accreditation criteria-4, entitled Continuous Improvement [16]. Therefore, programs are compelled to anticipate change with an emphasis on various skills that could affect the preparedness of graduates for the job market and pave the way for continuous reassessment of how the students are being educated [20].

Figure 2. The Continuous Improvement Process

Current Practice

It appears that assessment is driven by compliance with accreditation. In many instances, an institution has to fulfill requirements of a number of program accreditation assessments along with institutional (regional) accreditation assessment. In each of those cases, there are extensive assessment requirements, which generate excessive load on the body conducting the assessment, namely the faculty.

In a presentation at the 2014 ABET symposium [21], a survey had been conducted to assess the understanding of the attendees (faculty) regarding regional commissions and ABET assessment requirements. The participants (n=47) were asked four questions regarding their institution's regional accreditation, ABET (program) accreditation, their involvement in the assessment process, and if there was any common ground between ABET and regional assessment work. It appeared that a large number of the attendees (>40%) were not sure about any common grounds of assessment among the regional bodies. Furthermore, they were unaware of any similarities in the requirements between ABET's assessment and the regional commission's assessment. Consequently, many institutions are conducting independent, uncoordinated, and redundant assessments, requiring development of redundant instruments and result analyses. Therefore, too often, assessment is a valueless and unfocused effort for accreditation compliance.

As mentioned earlier, there are about six major regional accrediting bodies in the U.S. Each accrediting body has its own unique practices influenced by its distinctive and intrinsic economic and cultural attributes of its region [22]. However, their overall accreditation requirements and student learning outcomes assessment structures tend to be more alike than different [23]. At this juncture, it requires a conscious, proactive, well-designed, and coordinated effort to align assessment requirements to make the process more streamlined, focused, and meaningful.

Proposed Approach

As efforts are exhorted to try to make assessment more streamlined, focused, and meaningful, as well as lessen the burden on the faculty, there is a need to explore common ground among various accreditation assessment requirements through collaborative efforts. Consequently, the first step is to realize the similarities among the accrediting bodies in terms of assessment requirements and streamlining assessment planning and instruments.

Regional accreditation: Institutional (regional) accreditation, as opposed to discipline-specific accreditation/ assessment, usually does not specify course or curriculum content or instructional methods. Among the regional commissions, there are many commonalities in the accreditation standards. Additionally, a number of those standards align with program-level accreditation criteria. Table 1 shows the similarities among the regional accreditation standards.

It is evident from Table 1 that there are a number of common accreditation goals among the regional bodies, such as Mission and Goals, Planning, Resource Allocation, Student Learning, and Leadership. In summary, all of the regional commissions share a commitment to student learning by providing a basis for assessing accreditation practices. Generally, they require institutions to demonstrate the following (see also Figure 3):

1. Stating student learning outcomes (SLOs) that are directly related to institutional missions.
2. Evidence of a systemic process that assesses the attainment of the SLOs.
3. Availability of resources to support the SLOs.

Table 1. Similarities among the Regional Accreditation Standards (underlined)

Commission	Major Common Points Taken from Standard
Middle States (MSCHE)	Mission and Goals, Planning, Resource Allocation, and Institutional Renewal, Administration, Integrity, Institutional Resources, Leadership and Governance, Institutional Assessment, Student Support Services, Student Admissions and Retention, Faculty, Educational Offerings, General Education, Related Educational Activities, Assessment of Student Learning
New England (NEASC-CIHE)	Mission and Purposes, Organization and Governance, Planning and Evaluation, The Academic Program, Students, Faculty, Library and Other Information Resources, Financial Resources, Physical and Technological Resources, Public Disclosure, Integrity
North Central (NCA-HLC)	Mission, Teaching and Learning, Quality, Ethical and Responsible Conduct, Resources, and Support, Evaluation and Improvement, Teaching and Learning, Resources, Planning, and Institutional Effectiveness
Southern (SACS)	Institutional Mission , Institutional Effectiveness , Governance and Administration , All Educational Programs, Undergraduate Programs, Graduate and Post-Baccalaureate Professional Programs, Library and Other Learning Resources , Faculty , Student Affairs and Services, Physical Resources, Substantive Change Procedures and Policy, Financial Resources, Compliance with Other Commission Policies, Representation of Status
Western (ACCJC-WASC)	Institutional Mission and Effectiveness, Resources, Leadership and Governance,, Student learning Program and Services
Western / WASC Senior	Defining Institutional Purposes and Ensuring Educational Objectives, Developing and Applying Resources and Organizational Structures to Ensure Quality and Sustainability, Achieving Educational Objectives Through Core Functions, Institutional Learning, and Improvement, Creating an Organization Committed to Quality Assurance
The Northwest Commission (NWCCU)	Mission, Core Themes, and Expectations, Standard Three: Planning and Implementation, Effectiveness and Improvement, Resources and Capacity, Adaptation, and Sustainability, Mission Fulfillment

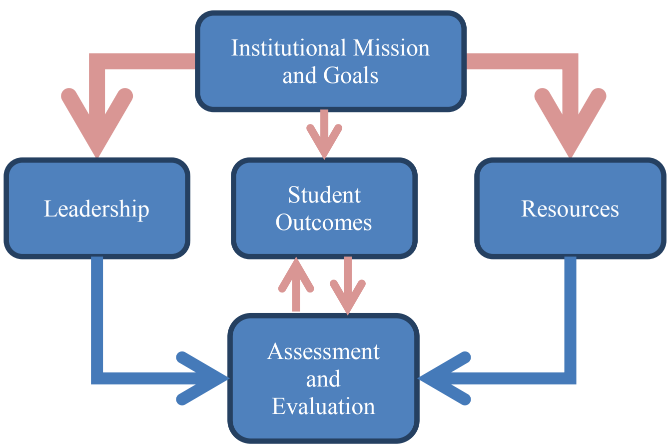

Figure 3. Fundamental Assessment Framework

Program level assessment: Program level assessment, unlike institutional/regional assessment, concentrates on how an academic program is contributing to the learning and development of students within a discipline**.** Since program-level assessments are more specific to a discipline, faculty are to focus within their context of technical program accreditation (e.g., ABET). It should be noted that, at the least, a number of general education student outcomes, for example communication skills, are common to most of the program-level accreditations. The summary of ABET's eight criteria (for technology accreditation) are taken from ETAC [16]: "It is the responsibility of the program seeking accreditation to demonstrate clearly that the program meets the following criteria:

1. Students: Student performance must be evaluated. Student progress must be monitored to foster success in attaining student outcomes, thereby enabling graduates to attain program educational objectives.
2. Program Educational Objectives: The program must have published program educational objectives that are consistent with the mission of the institution, the needs of the program's various constituencies, and these criteria. There must be a documented, systematically utilized, and effective process, involving program constituencies, for the periodic review of these program educational objectives that ensures they remain consistent with the institutional mission, the program's constituents' needs, and these criteria.
3. Student Outcomes: The program must have documented student outcomes that prepare graduates to attain the program educational objectives. There must be a documented and effective process for the periodic review and revision of these student outcomes.
4. Continuous Improvement: The program must regularly use appropriate, documented processes for as-

sessing and evaluating the extent to which the student outcomes are being attained. The results of these evaluations must be systematically utilized as input for the continuous improvement of the program.

5. Curriculum: The curriculum must effectively develop the relevant subject areas in support of student outcomes and program educational objectives.
6. Faculty: Each faculty member teaching in the program must have expertise and educational background consistent with the contributions to the program expected from the faculty member. The faculty must have sufficient responsibility and authority to improve the program through definition and revision of program educational objectives and student outcomes as well as through the implementation of a program of study that fosters the attainment of student outcomes.
7. Facilities: Classrooms, offices, laboratories, and associated equipment must be adequate to support attainment of the student outcomes and to provide an atmosphere conducive to learning.
8. Institutional Support: Institutional support and leadership must be adequate to ensure the quality and continuity of the program. The resources available to the program must be sufficient to acquire, maintain, and operate infrastructures, facilities and equipment appropriate for the program, and to provide an environment in which student outcomes can be attained."

ABET versus Regional Commissions: As seen in the previous section, the regional commissions have a number of common assessment requirements for accreditation. Furthermore, the regional commissions have a number of common assessment requirements comparable to program-level requirements, particularly with the ABET SLOs (see criteria 3). Table 2 shows an example of the similarities between regional and ABET assessment requirements.

For the sake of comparison, MSCHE can be taken as a reference for the institutional accreditation, since this commission accredits current the authors' institution, the New York College of Technology. A similar approach can be implemented for other commissions as well. The New York College of Technology engineering technology program is accredited by ABET; therefore, ABET was used as the reference for program-level accreditation. The above discussion paves the way to an initiative of alignment of accreditation and assessment activity of ABET with MSCHE. This approach can be implemented for other relevant scenarios.

ABET vs. MSCHE: Figure 4 depicts the overall alignment (color-coded) of ABET criteria with that of MSCHE. ABET criterion 3 defines the student outcomes, and MSCHE addresses similar outcomes in standards 11 and 12. Figure 4 is expanded into Table 3, where detailed components of alignment are shown. Table 3 illustrates the common assessment points that can be aligned to increase efficiency (e.g., development of common assessment rubrics).

While program-specific learning outcome assessments may not be comparable among the accrediting bodies, the general education assessments are. This very common ground has to be exploited in order to bring about assessment efficiency. Accreditors do not prescribe an assessment model; however, they expect that an institution's assessment activities are supported by the institutional leadership. Typically, the regional accreditors explicitly mention in their standards faculty involvement in the assessment process. After all, who knows more about the students and their learning process than the faculty members? However, the faculty members often feel that assessment is an additional and unpleasant burden. Assessing for different accreditors overburdens the faculty; thus, it is imperative to work towards efficiency of assessment at the institutional level by searching for ways to collaborate among various disciplines that can support the overall assessment process. Furthermore, faculty involvement in the assessment process will require a paradigm shift, where it views assessment as a form of scholarly work [24].

Too often, assessment is reactive, irregular, and vague. It is imperative that there be a proactive, systematic, and

Table 2. Similarities between Regional and Program-Level Accreditation

Program level	Regional
ABET - Criterion 3 The program must demonstrate documented student outcomes that prepare students to attain the program educational objectives. Additionally, there must be systematic documented process for the periodic revision of these student outcomes.	Middle States Commission on Higher Education – Standards 12 and 14 New England Association of Schools & Colleges – Standard 4 North Central Association of College and Schools– Criterion 4 Southern Association of Colleges and Schools – Standard 3 Western Association of Schools and Colleges Community and Junior Colleges – Standard 2 Senior College and University Commission – Standards 2 and 4

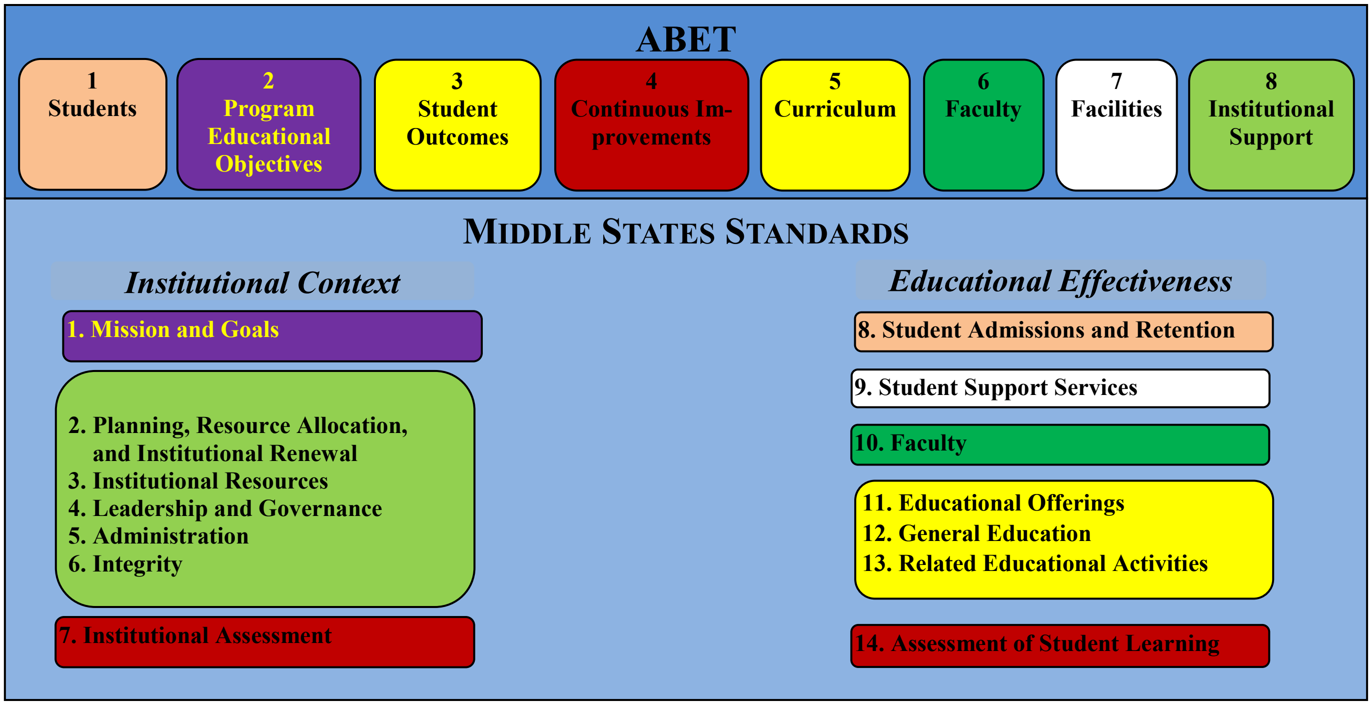

Figure 4. Alignment of ABET Criteria with MSCHE

meaningful assessment. One of the important components of assessment is the instruments. To gain needed efficiency in the assessment process, it is imperative to refer to previous sections and exploit common grounds to carefully design assessment instruments that can be used across disciplines as well as at a regional level. At the beginning, focus should be on the general education (professional skills) assessments. A number of empirical studies established that professional competencies, or soft skills such as communication and interpersonal skills, are much more important for job performance than are technical abilities [25]. Some experts believe that professional competencies are twice as important in contributing to excellence as is intellect alone [26].

Successful transition from an academic institution to the workplace requires that graduates possess technical and social skills in order to function effectively with colleagues because, being new graduates, their attitudes, interests, and values may not be at a professional level (professional identity development is gained through the process of professional socialization) [27-29]. General education assessment is not only important but also covers most types of accreditation assessment. Therefore, assessing the general education outcomes serves a number of purposes. Consequently, the development of an assessment instrument should be the first step towards efficiency via alignment of the program-level and regional accreditor learning outcomes.

Future Work

This work paves the way for future work, where development of common assessment instruments and planning for general education assessments are to be addressed. It can also lead to other assessments of resources, facilities, institutional commitment, etc.

Conclusion

Assessment is an integral part of the educational process. It helps to measure success in terms of preparing students for the workplace. It is also an accreditation requirement. In many instances, an institution needs to fulfill requirements of a number of accreditation assessments. Lack of coordination and planning results in assessment being a burdensome, redundant, and meaningless effort without any value. At this juncture, it requires conscious, proactive, well-designed and coordinated efforts to align assessment requirements to make it streamlined, focused, and more meaningful. In this study, the authors demonstrated a pathway to attain the needed efficiency and success in assessment through exploiting common accreditation requirements and initiating collaborative efforts for streamlining assessment planning and instruments.

Table 3. Alignment of Assessment Components (underlined)

ABET Criterion	MSCHE Standards
Relevant criterion as stated in ABET criteria [16]: **"**..these student outcomes must include, but are not limited to, the following learned capabilities **3. Student Outcomes (SO)** **(**a) … <u>apply knowledge of mathematics, science</u> (e) an ability to identify, <u>formulate, and solve engineering problems</u> (g) an ability to <u>communicate effectively</u> (k) an ability to use the techniques, <u>skills, and modern engineering tools</u> necessary for engineering practice	**Relevant standards as it appears in MSCHE standards [9]:** **"**Standards at a Glance **11. Educational Offerings:** Student learning goals and objectives, including <u>knowledge and skills, for its educational offerings.</u> **12**. General Education: The institution's curricula are designed so that students acquire and demonstrate college-level proficiency in general education and essential skills, including at least <u>oral and written communication, scientific and quantitative reasoning</u>, critical analysis and reasoning, and technological competency.
5. Curriculum: The curriculum must effectively <u>develop the relevant subject areas in support of student outcomes and program educational objectives</u>…	**11. Educational Offerings: t**he institution's educational offerings display <u>academic content, rigor, and coherence appropriate to its higher education mission</u>
7. Facilities: <u>Facilities Classrooms, offices, laboratories, and associated equipment must be adequate to support attainment of the student outcomes</u> and to provide an atmosphere conducive to learning. ... **8. Institutional Support:** <u>Institutional support and leadership</u> must be adequate to ensure the quality and continuity of the program. <u>Resources including institutional services, financial support, and staff (both administrative and technical) provided to the program must be adequate</u> to meet program needs. "	**3. Institutional Resources:** The human, financial, <u>technical, physical facilities, and other resources necessary to achieve an institution's mission and goals</u> are available and accessible. In the context of the institution's mission, the effective and efficient uses of the <u>institution's resources</u> are analyzed as part of ongoing outcomes assessment."

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Using Intelligent Transportation System Technology to Manage Work Zones in Highway Corridors in Lagos, Nigeria

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Abstract

The management of road traffic on the existing lanes in work zones when construction work and road maintenance are in progress continue to be an issue requiring improvements. A work zone is a segment of roadway where construction, maintenance, and installation of utilities at existing roadways occur. Intelligent transportation system (ITS) technology is a tool that utilizes advanced communications, computer, and information technologies to improve transportation systems, including segments of roads where workers are present. In this study, the author investigated the need for improving the safety of road workers exposed to accident risks in Lagos, Nigeria, by examining traffic speeds, protection methods, and traffic enforcement in work zones. The One-Sample Wilcoxon Signed Rank Test was used to test the hypothesis. Findings indicated that in the work zone, motorists traveled above 50 km/h where there was lack of enforcement and standard temporary traffic control measures. It was recommended that portable ITS technology be provided to caution motorists who were traveling at high speeds; the speeds of motorists should be captured so that law enforcement agents could penalize violators for the purpose of mitigating accident risks to roadway workers and motorists in work zones.

Introduction

The use of technology for reshaping societal activities was applied to transportation, construction, and other industries in order to enhance productivity, reduce costs, improve safety, and provide services. Perennial traffic issues have warranted developed countries such as the U.S., Japan, and Western Europe to deploy and apply intelligent transportation system technology (ITS) to manage and improve incidents and traffic flow in their respective cities. Developing countries such as Nigeria are still wallowing in such traffic issues, which include management of work zones.

A work zone is a segment of roadway where activity takes place. Such activities include maintenance of existing roadways, construction of new elements, or non-roadway work (e.g., utility installations or repair). In many cases, road users recognize active work zones by specific highway signing, speed reduction, change in traffic patterns, use of specialized traffic control methods, and/or the presence of materials, equipment, and workers [1]. Based on previous studies of motorist behavior in work zones, it was revealed that speeding, abrupt deceleration, and inadequate distances between preceding vehicles occurred frequently in work zones. Relatively speaking, such behavior is high risk and deemed to have a negative impact on traffic safety [2]. The following major factors contribute to work zone crashes [3]:

- Drivers are inattentive, misjudge, and disregard traffic control in the work zone.
- Inefficient traffic control on travel lanes.
- Driver behavior, such as aggressive driving, impairment, speeding, lack of awareness of work zone existence.
- Complex highway conditions, including geometry alignments and poor pavement.
- Inclement weather conditions, such as heavy rain and fog that causes poor driver visibility.

Lagos is a metropolis with traffic management situations that expose workers in work zones to accident risks. Crash impacts have led to injuries and fatalities of road workers, especially highway sweepers, who have lost their lives when knocked down by vehicles as a result of high traffic speeds of approaching vehicles in a work zone [4]. The updated 2013 Nigerian Highway Manual for maintenance works indicated the need for safety of highway users, maintenance personnel, and the work. In the document, it stated that there were artificially created humps to reduce vehicle speed to lane entry. The humps were made of premixed paving materials, thick wooden plans, or shaped baulks of wood, which can constitute danger. They noted that such humps on public highways should be supported by advisory signs showing safe speeds. While the method of controlling traffic currently does not constitute a permanent ITS installation, at least the work zone in Lagos requires the use of portable ITS technology as a supplementary measure to improve safety in work zones.

When motorists are not aware of the presence of work zones and are not cautioned and/or penalized by law enforcement officers for speeding, danger to road workers is imminent. Between June 2006 and May 2014, about 1579 deaths were documented for 620 crashes that occurred in

Lagos [5]. Lagos was ranked highest among states in Nigeria for the number of fatalities during the period. Available data did not classify accidents that occurred in work zones in Lagos.

Traffic management strategies have been tried in the study area but their ineffectiveness initiated the recommendation of ITS technology for use for the free flow of traffic in managing congestion at through-traffic areas in Nigeria's major cities [6]. However, consideration was not given for its use for safety in work zones. The only study found was for a work zone audit in Kano, Nigeria, that noted drivers' violation of imposed speed limits, lack of enforcement, and the use of substandard traffic control devices, based on the Manual on Uniform Traffic Control Devices (MUTCD) instead of the Nigerian Highway Manual [7]. The study did not recommend the use of ITS technology. However, this current study investigated traffic speed, observed and documented the perception of road workers present on the roadway almost every business day, as well as control measures in Lagos metropolis, which is the commercial center of Nigeria. The author also narrated and recommended the application and deployment of portable ITS technology towards supplementing any temporary traffic control measures used to mitigate risks to road sweepers, construction workers, as well as motorists in work zones in Lagos, Nigeria.

Problem Statement

Workers are mandated to perform duties on road segments, which require construction, maintenance, or sweeping on the roads of Lagos. The work zone is a dangerous location that requires worker protection and information to motorists ahead of work zones for driver awareness and speed enforcement. The application of portable ITS technology would help mitigate potential incidents impacting road workers by providing adequate information on the presence of work zones and speed limits, and assist law enforcement agents in speed enforcement in work zones in Lagos.

Application of ITS Technology

ITS technology integrates modern communication and information technology into the transportation system in order to monitor traffic in real-time and alleviate traffic congestion, incidents, pollution, etc. [8]. Government agencies apply ITS technology to monitor and manage traffic flow, particularly in urban cities. Work zone ITS installations can enhance transportation and improve safety and mobility in and around work zones, while the information provided could be in the form of real-time traffic conditions, such as delays through a work zone or recommended diversion of routes for motorists to change travel behavior or warnings on traffic conditions. For instance, such a warning could indicate traffic stops or slow truck encroachment from a work zone [9]. An ITS installation in a work zone could utilize existing fixed infrastructure, but the system for the study area would utilize portable systems, because they are temporary at road segments and there are currently no permanent systems for solving traffic issues. However, permanent systems used to solve traffic issues can play a limited role in construction and maintenance activities. It is important to note that video monitoring by installed cameras can be useful, but the situation in work zones could constitute detection problems because of a shift in activities, which include work sections, lane shifts, and road traffic [10].

Dynamic Lane Merging (DLM) System

The dynamic lane management (DLM) system is an intelligent work zone traffic control system applied in the work zone area to control traffic. The system responds to changes in traffic in real-time with the aid of traffic sensors. DLM is designed to automatically react to the changing queue length and flow conditions and adjust the length of a no-passing zone. As congestion occurs at a particular point, the no-passing zone would be moved upstream to a point where traffic would have time and space to merge without having an impact on moving vehicles at a defined speed [11]. The traffic conditions would definitely vary during peak and off-peak hours. The dynamic no-passing zone would encourage motorists to merge ahead through the open lanes before reaching the closed lanes. Two DLM strategies were identified as early and late merge. The early merge advises drivers to change from the closed lane to the open lane before arriving at a forced point of merging in order to avoid congestion. This appears to work best when the traffic volume is low and the average speed is high. It creates the non-passing zone. The late merging strategy allows motorists to remain in their lanes until they get to the merging point. In this case, the traffic volume is high and speed is low. Drivers take turns at the merging point to stay in the open lane [12].

Variable Speed Limit (VSL) System

The variable speed limit (VSL) system is a type of ITS technology designed to set the speed limits in a work zone, based on traffic conditions in real-time. VSL manages the speed of traffic approaching and traveling through work zones, based on the current situation of traffic conditions as well as the nature of the construction site. This technology could utilize portable trailers to detect traffic speed in a work zone, based on traffic flow characterized by the road conditions and may use sensors to monitor prevailing traffic or input from transportation professionals and law enforcement agents in posting appropriate enforceable speed limits on a changeable message sign (CMS) [11]. The recommended speed limit for conditions of merging the traffic is a function of the average speed of traffic [13]. Hence, the VSL displays the speed limit through the CMS based on average speed captured by the sensor. The displayed speed limit could change at intervals, based on traffic condition.

Real-Time Information System

Traffic conditions in work zones change and sometimes affect mobility, particularly when road capacity has been reduced and traffic volume increased as a result of activities in a work zone. This results in delay to motorists. The real-time information system provides information ahead to drivers on traffic conditions when approaching a work zone. The system utilized sensors and cameras to monitor real-time traffic conditions. The sensor data were used to calculate the speed, delay, and travel time, and automatically display the messages on a dynamic message sign. The motorists could make a decision to take an alternate route.

Deployment of ITS Installations in Work Zones

The deployment of ITS technology needs to be efficient and effective, based on available resources, as well as determination of the nature and size of work to be performed in the work zone so as to address impending issues. Effective deployment of ITS technologies depends in part on the knowledge of which technologies will most effectively address the issues of congestion and safety. In order to enhance performance of government agencies in providing safety measures for work zones, an ITS installation that encompasses a broad range of wireless and wired communication-based information and electronic technologies should be deployed [14].

Relative to the scope of the project and conceived ITS technology to address safety and traffic issues in the work zone, a plan as well as the system process must be reviewed by the agency to ensure effectiveness and efficiency of system deployment. While the project was deemed to be temporary, the operational and maintenance costs during activities in the work zone must be reasonable. This technology could use field devices such as closed-circuit television (CCTV) cameras installed on the highway corridors to capture images and send them to a traffic management center (TMC) at a remote location. The TMC consists of equipment that includes large screen monitors, servers, computers, and cable networks that link the devices from the center to the field.

Relative to Lagos metropolis, the work zones do encompass construction/maintenance of utilities, such as street lighting, pipe work, and cables. It also includes road construction, pavement work, and road sweeping. Road sweeping is predominantly performed manually during off-peak hours during the daytime. The work zone sometimes can interfere with road intersections, where traffic signals are installed and operational. Such traffic signal cycles would be interrupted. If there was an existing ITS technology deployed in Lagos, as suggested by various authors, such work zones at an intersection could be observed from an available TMC from which the lights could be synchronized to manage lanes and give green to approaching lanes having high traffic volume. An adaptive signal control system could perform adjustments of signal timing in a determined jurisdiction from a remote location [15].

As observed, portable ITS technology can be deployed effectively at different work zones in Lagos. It has been deployed by different agencies to monitor traffic and manage mobility and safety during construction. It provides solutions for deployment, maintenance, operation, and remobilization of monitoring systems, because road characteristics change during construction [16]. Hence, the system operates in the form of mobile traffic monitoring and management. It uses portable sensors to collect traffic data along with integrated portable dynamic message signs to display speed and/or delay information in real-time. The technology can detect traffic flow information in a work zone and deploy a number of data collection trailers using non-intrusive traffic sensors to measure traffic flow approaching and traveling through a work zone. Based on the measured conditions, estimated travel times are determined and displayed for motorists on portable changeable message signs in advance of the work zone. The messages are conveyed to motorists and workers through devices such as CMSs, highway advisory radio (HAR), in-vehicle GPS, alarms, and Internet websites. The type of messages displayed advises drivers of slow speeds ahead, travel time, delays, and guidance on the use of alternate routes. The system is comprised of a vehicle -mounted CMS that can be used to display information on specific road conditions, such as when men are working, or warn motorists of incidents, speed monitoring, or indicate speed limit [17].

Communication System

This efficient communication method is important for the system's operation and reliability. A mobile ITS needs to be easily scalable to fit the needs of a specific project as well as respective phases of the project [18]. Deployment of the ITS can make use of fiber optic cable (FOC), where permanent systems exist, as well as wireless technology as a means of communication. The portable system would rely more on wireless technology. The wireless system involves transfer of information over a distance without using electrical conductors or wire lines. It would utilize radio waves and/or microwaves to maintain communication channels with the central base station server. Excessive cost of maintenance, excavation, and disruption to traffic and public needs would be reduced overtime. The drawback of the technology is that it is affected by weather, other wireless devices, and terrain.

Similar to the deployment of fixed infrastructure, portable ITS technology utilizes field devices that consist of cameras and sensors that are temporarily positioned in work zones. It captures data and enables data flow from the field to other field devices, vehicle, and a control center. In a work zone, a traffic management vehicle, which collects data, is equipped with a mounted camera and a telescopic boom. The base station server processes data collected from the sensor and calculates delays at stations where sensors are present. When the communication system in a work zone engages wireless Internet, an Internet Protocol (IP) address that has high priority for fast flow of information through the network would be needed. The system would be interoperable through the use of appropriate standards that would enable the devices to exchange information properly and as well be interchangeable with products from different manufacturers. The ITS installations in work zones would provide significant benefits to agencies and those affected by the mobility and safety impacts of road construction and maintenance in work zones [9]. Figure 1 is a schematic diagram for speed control and lane merging, based on the current methods in work zones in Lagos.

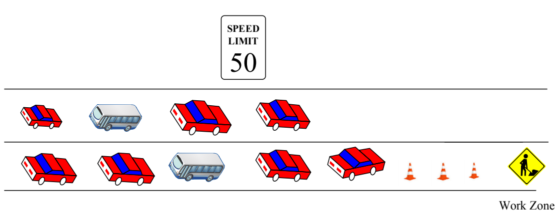


Figure 1. Current Situation when Workers were Present in the Work Zone

Figures 2 shows a schematic diagram for speed control and lane merging on a work zone with deployed ITS technology in Lagos.

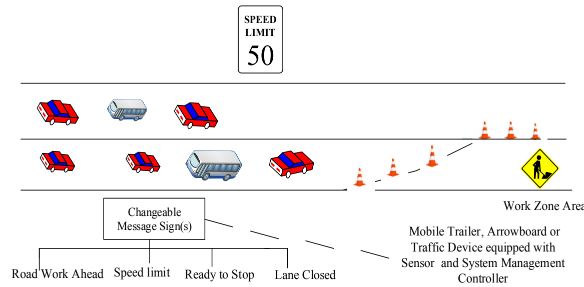


Figure 2. Application of ITS Technology

Since a permanent ITS installation is not in place, the portable ITS in Figure 2 would be the immediate safety solution.

Methodology

Relative to the methodology employed in this study, the author physically observed situations from spots in work zone segments on major trunk road networks during the month of July, 2014. The selected roads included Funsho Williams Avenue, Ikorodu Road, Apapa Oshodi Expressway, and Kirikiri Road. A spot speed test with a stop watch was conducted for 100 vehicles during off-peak hours. The author randomly interviewed road workers and traffic agents and also observed the types of control measures at different segments of work zones along Lagos road corridors.

Based on this cross-sectional study, the interviews were conducted randomly with 56 workers in work zones, while 15 traffic agents were interviewed randomly within Lagos metropolis. Structured and closed-ended questions were asked in order to determine if there was traffic enforcement in work zones as well as a perception of workers on control measures in work zones. Data gathered were analyzed using Microsoft Excel and SPSS 20. The spot speed test was performed to determine both the 50^{th} and 85^{th} percentile of traffic speed at Funsho Williams Avenue, which is a Trunk 'A' road. The Shapiro Wilk test was used to test for normality. Based on the outcome, the One-Sample Wilcoxon Signed Rank Test, a non-parametric test, was used to test the following hypothesis:

Ho: The median speed of highway vehicles passing the work zone is 50 km/hr.

Ha: The median speed of highway vehicles passing the work zone is greater than 50 km/hr.

Findings

The data gathered were analyzed using Microsoft Excel as well as SPSS version 20 for descriptive and inferential analyses. Based on the outcome, Figure 3 indicates that 94% of all the responding traffic agents did not control traffic, while 6% did. Also, 79% of the traffic agents did perceive slowdown signs, while 21% did not; 87% of the traffic agents did not perceive speed limits in work zones, while 13% did perceive speed limits.

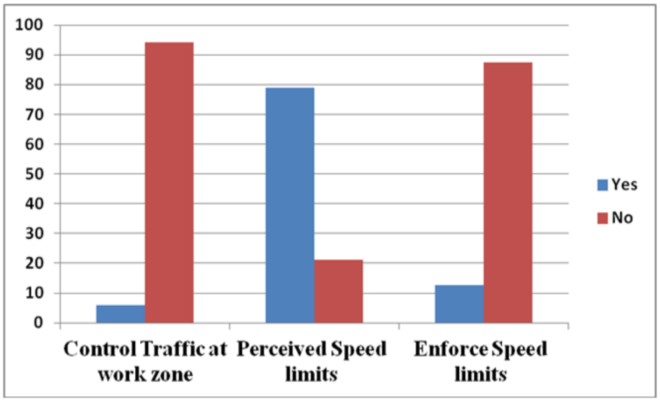


Figure 3. Responses of Traffic Agents to Traffic Control and Enforcement in Work Zones

Relative to protection of workers in work zones, Figure 4 indicates that 77% of the workers perceived protection measures, while 23% did not perceive protection measures. And, 56.7% of workers indicated that they placed barricades on roads, while 43.3% did not indicate placing barricades.

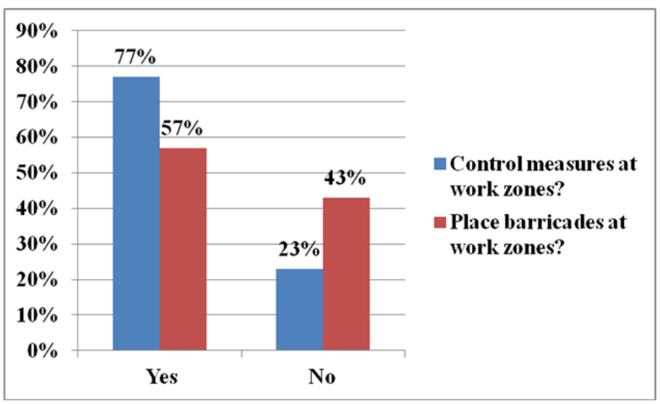


Figure 4. Responses of Workers to Work Zone Protection Measures

Figure 5 is a line graph indicating the cumulative percentage of the frequency of vehicle speed in work zones. It shows that only 45% of the motorists drove below 56.4 km/h.

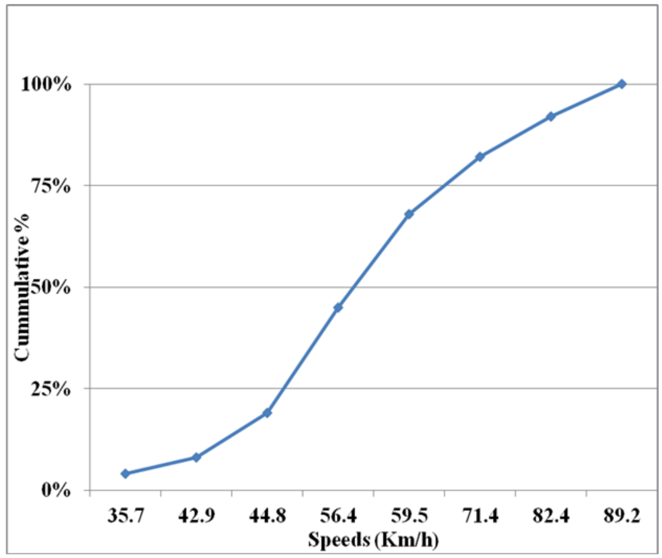


Figure 5. Cumulative Percentage of Vehicle Speeds in Work Zone Measures

Table 1 indicates the speed that was calibrated for 100 vehicles, based on the time it took each vehicle to traverse the spot where data were collected from a predetermined distance of 60 meters.

Table 1. Frequency Distribution Table for Traffic Speeds in Work Zones

Sec.	Speed (Km/h)	Frequency of vehicles	Cum Freq	Cum %	Speed Percentile
6.0	35.7	4	4	4%	
5.0	42.9	4	8	8%	
4.8	44.8	11	19	19%	
3.8	56.4	26	45	45%	50th
3.6	59.5	23	68	68%	
3.0	71.4	14	82	82%	85th
2.6	82.4	10	92	92%	
2.4	89.2	8	100	100%	

The frequency and speed range where the 50th and 85th percentile speed of vehicles lie are indicated in Table 1. The actual median speed for the 50th percentile can be determined using Equation (1):

$$S_D = \frac{P_D - P_{\min}}{P_{\max} - P_{\min}}\left(S_{max} - S_{\min}\right) + S_{\min} \qquad (1)$$

where, S_D = speed at P_D; P_D = Percentile desired; Pmax = higher cumulative percent; Pmin = lower cumulative; Smax = higher speed; and, Smin = lower speed [19].

For this study, Equation (1) was applied based on the information in Table 1 in order to determine the actual median speed (50th percentile), as shown in Equation (2):

$$\frac{50\% - 45\%}{68\% - 45\%}\left(59.5km/h - 56.4km/h\right) + 56.4km/h = 57km/h \quad (2)$$

Equation (2) indicates that 57 km/h was the actual median (50th percentile) speed driven by motorists in the work zone. Similarly, Equation (1) was applied to determine the actual 85th percentile speed, as shown in Equation (3):

$$\frac{85\% - 82\%}{92\% - 82\%}\left(82.4km/h - 71.4km/h\right) + 71.4km/h = 74.7km/h \quad (3)$$

Equation (3) indicates that the 85th percentile of the motorists drove at 74.7 km/h in the work zone. Speeds in the work zone were expected to be drastically reduced from normal through traffic. A preliminary investigation was performed using the Shapiro-Wilk test for normality. As indicated in Table 2, the significance value was 0.000 (P< 0.05). It failed the normality test.

Table 2. Tests of Normality

	Kolmogorov-Smirnov *			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Vehicle Speed	.244	100	.000	.913	100	.000

* Lilliefors Significant Correction

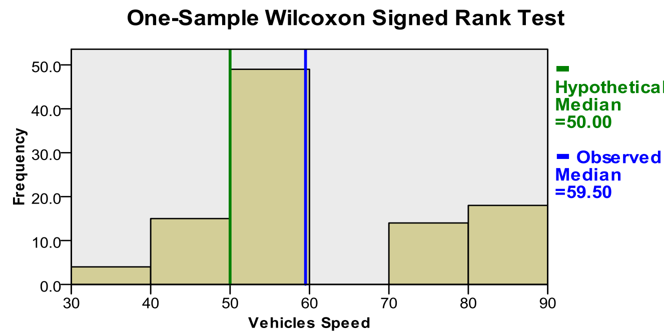
Because the data violated the normality assumption, the One-Sample Wilcoxon Signed Rank Test, which is a non-parametric test, was used to test the hypothesis. The null hypothesis stated that the median speed in the work zone is 50 km/hr.

Table 3. Hypothesis Test Summary

Null Hypothesis	Test	Sig	Decision
The median of vehicles Speed equals 50.00	One-Sample Wilcoxon Signed Rank Test	0.00	Reject the null hypothesis

Note: Asymptotic significances are displayed. The significance level was 0.05

As depicted in Table 3, the test indicated that it was statistically significant with p = 0.000 (p<0.05) and z = 7.028. Since SPSS version 20 uses 0.05 alpha as its default for two -tail tests, considering that the alternative hypothesis was directional, it was statistically significant at p = 0.000 (p<0.05/2) for one-tail test. Therefore, the null hypothesis was rejected. In essence for the vehicle speed observed in the work zone, Figure 6 indicates that the observed median speed was 59.5 km/h, which was greater than 50 km/h that was hypothesized and expected to be tolerant.



Total N	100
Test Statistic	4,560.000
Standard Error	289.570
Standardized Test Statistic	7.028
Asymptotic Sig. (2-sided test)	.000

Figure 6. One-Sample Wilcoxon Signed Rank Test

Discussion

Based on the findings, there were no enforcements in work zones in Lagos. Motorists assumed that the driving patterns on these segments of the roadway were in the same manner when driving along through traffic. Workers in work zones were not well protected by relevant agencies. Relative to responses by the workers, there were signs for speed limits. The speed limits were not variable based on traffic conditions in work zones. In short, the response appeared contrary to the author's observation on the field, because the areas where sweepers worked lacked speed limits.

Workers could not control traffic patterns and speeds of the approaching vehicles. Hence, most of them placed barricades on the roadway to shield themselves from being hit by approaching vehicles. It is important to note that, when work was in progress, substandard materials were used to barricade the road. Such signs indicated "Men at Work," "Slow down," as well as pointed arrows on wooden materials for lane changes. work zone safety, as addressed in the Nigerian Highway Manual [20], was not properly followed.

While some pavements were marked, some were not marked. The speeds of most of the vehicles in the work zone were high and above a tolerable speed needed at such segments of the roadway. Law enforcement agents were not present to determine if motorist speeds were beyond speed limits. Hence, they need to be present to caution and/or enforce the law. The Lagos traffic law stipulated a fine of 100,000 Naira or imprisonment of two years for offenders exceeding prescribed speed limits [21]. The law was not specific on such violations in work zones.

Conclusions

The use of ITS technology has not been applied at work zones in any Nigerian cities. Its application when workers are engaged in road construction, maintenance, utility installations, and manual sweeping at segments of major trunk roads in Lagos would improve safety. The workers are exposed to dangers from high-speed vehicle traffic. The work zone area also needs to be controlled with standard signs that should reflect the 2013 updated Nigerian Highway Manual for maintenance of roadways. Irrespective of the signs, the real-time information received by motorists through the CMSs would enable drivers to be aware of impending activities on the roadway, which might enable them to take alternative routes if necessary. The speed limits displayed to motorists would reduce excessive vehicle speeds in work zones. In addition, it would assist law enforcement agents in enforcing. Those who exceed work zone speed limits would be fined. A double fine, compared to violations at through traffic highway sections, is recommended in order to help curb such violations in work zones.

The technology would also help mitigate accidents, injuries, and fatalities to road workers, as well as improve overall traffic management. In essence, the Lagos state government could be less involved in litigations and any compensations resulting from fatalities due to its negligence of adequate protection to its personnel that might be injured or killed while sweeping, constructing, and maintaining the roadway.

Since there was no permanent ITS technology in place in Lagos, the portable ITS was recommended because it could rapidly be deployed to improve work zone safety. For sustainability, the Lagos state government would provide adequate funding, train its personnel on deployment and maintenance, as well as provide measures to protect devices and other equipment from theft overnight at work zones. For future study, a detailed model for work zone planning and selection of ITS technology methods would be warranted when the technology has been in operation in the geographic area.

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Biography

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Technology-Driven University and Community College Collaboration: Faculty Training on ARM Microcontrollers

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Abstract

The electronics world is experiencing a complete transformation in the electronic design of new products. The movement to reconfigurable digital systems using microcontrollers is sweeping the electronics world in the rush to create smaller, faster, and more flexible consumer and industrial devices. Microcontrollers are becoming one of the most exciting devices in history. At the core of microcontroller technology is the ARM microcontroller. The ARM-based embedded system is the industry standard with current sales at 5 billion units per year, and it will increase as the demand for powerful, low-power electronics increases. Exposure to and training in this technology is critical for engineers and technicians in order to remain competitive. To meet the need for these design skills, university programs are updating curricula with courses in ARM-based microcontroller technology. Partners on this project have years of successful National Science Foundation (NSF) project implementations, training-the-trainer hundreds of instructors and introducing thousands of students to advanced reconfigurable electronics technologies. In this paper, the authors discuss the offering of a two-day faculty professional development (educate the educator) workshop on ARM-based microcontrollers for electrical engineering technology faculty, as part of a National Science Foundation—Advanced Technological Education (NSF-ATE) grant. The project goals are to provide colleges with up-to-date educational equipment with current technological solutions. In summary, this project will provide the training and educational resources and promote best practices for community college and university instructors to enable them to teach new hardware technologies to a broad range of students, including those who have not previously had access to this level of training and career choices.

Introduction

Industrial, commercial, and consumer electronics of all types have experienced a transformation over the last decade, brought on by revolutionary advances in reconfigurable components such as FPGAs, systems-on-chip (SoC's), and ARM-based microcontrollers. These advances have placed more computing resources with lower power requirements and greater flexibility at engineers' disposal than at any other time in history. As educational institutions at all levels endeavor to make effective use of new technology, they are often impeded by long learning curves and entrenchment in existing curricula. Two-year and four-year graduates in STEM fields must be prepared to work with new, reconfigurable systems. In the last decade, programmable logic devices have become prevalent and FPGA-based reprogrammable logic design has become the design media of choice. As a result, industrial use of FPGA and microcontroller technology in digital logic design is increasing rapidly. Correspondingly, the need for highly qualified logic technicians and engineers with FPGA and microcontroller expertise is also increasing rapidly. To meet the need for these design skills, university programs are updating curricula with courses in hardware description languages and programmable logic design.

A recent survey was sent to government and industry, designed to gauge the necessity for providing this training. Forty organizations responded and the results showed overwhelming support for incorporating FPGA design skills into two- and four-year electrical and computer engineering technology programs. Results showed that almost 80% of respondents viewed knowledge of FPGA and microcontrollers as a critical skill for making graduates more employable and marketable [1]. Responding to this need, the community college and its partner institutions (including Michigan Technological University, the University of New Mexico, and Chandler-Gilbert Community College) proposed to build on previous successful projects utilizing highly qualified academic and industry-experienced resources to develop and implement online and technology-enabled courses and learning projects that will be scaled up to reach significant numbers of diverse instructors and students over a large geographic area.

Research Background

Microcontrollers are becoming one of the most exciting devices in history. Average future homeowners will have every aspect of their home designed around them. While an FPGA can serve as a control system, every other device—lights, home electronics, appliances, etc.—will be interfaced through microcontrollers. Utilizing these tools, homeowners will be able to log into their "homes" and control every electronic component from their handheld devices. The same will likely be true for cars, businesses, and limitless other possibilities through the use of microcontrollers. An "Internet of Things" can only be possible with modern microcontrollers. One microcontroller can manage hundreds of sensors through a single inter-integrated circuit protocol (I2C) bus. Figure 1 shows a microcontroller system-on-chip integrated circuit containing a processor, memory, and programmable input/output peripherals.

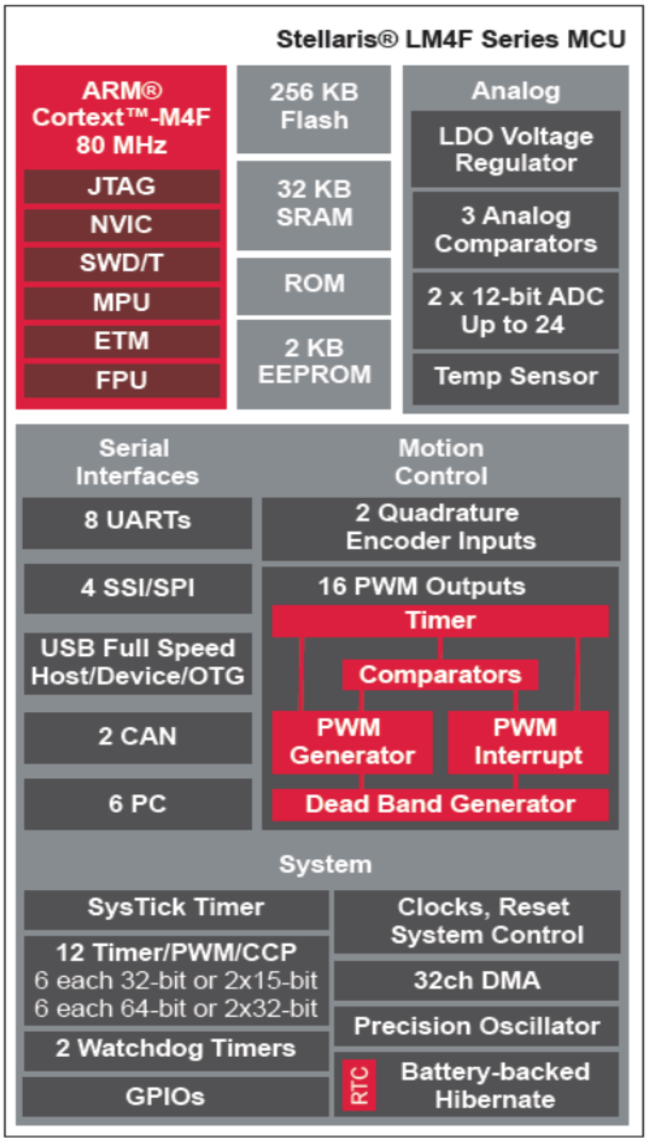

Figure 1. ARM Overview

The microcontroller the team uses for the course is the TI ARM [2], an ARM-based processor. The ARM processor is an industry standard. Isuppli [3, 4], a well-known market research firm, states that sales of ARM processors, currently at 5 billion units per year, will increase as the demand for powerful, low-power electronics increases. Exposure to and training in this technology is critical for engineers and technicians in order to remain competitive. Microcontrollers are small and have low power consumption and analog capability compared to FPGAs. Microcontrollers can be mounted in everything from light switches to microwave ovens. Usually complex digital systems will incorporate FPGA as the main controller and utilize embedded systems for sub-circuits' control. It is not necessary for technicians to be experts in all aspects of these technologies; however, they need at least a working knowledge of these systems.

Research [5] identifies faculty development as a major concern. Universities need to develop programs to allow their faculty to advance professionally [6]. This current project enables the updating of the Embedded Systems curriculum to meet the industry demand by supplying qualified engineers and technicians, who have extensive hands-on experience with current design tools. Additionally, the approach for faculty development targets the faculty members who acknowledge the need to update their curricula but do not have the time or training to pursue it. Professional development plays a crucial role in the career-long growth of faculty via theory, research, and collaboration with colleagues. Additionally, it opens doors for better understanding of instructional concepts and teaching practices [7]. Professional development connects faculty across disciplines and career stages, diversifying learning to the benefit of all.

Curriculum Development: Microcontroller Faculty Professional Development Workshop

This workshop begins by exploring the world of microcontrollers: Who uses them and why? The hardware interface is examined and instructors learn how the interface provides input and output using easy-to-follow examples. Items such as temperature sensors and timers are used in simple projects. This class is designed to help faculty learn how to fully utilize the hardware. The design tool uses a free software environment. At the end of the workshop, each instructor receives a free prototype platform and free design environment software. Figure 2 shows the microcontroller course flow. Topics include: Microcontroller 101, Hardware Overview, and Intro to Programming. Participants not only learn how to operate the microcontroller but also how it works and how to create advanced designs, such

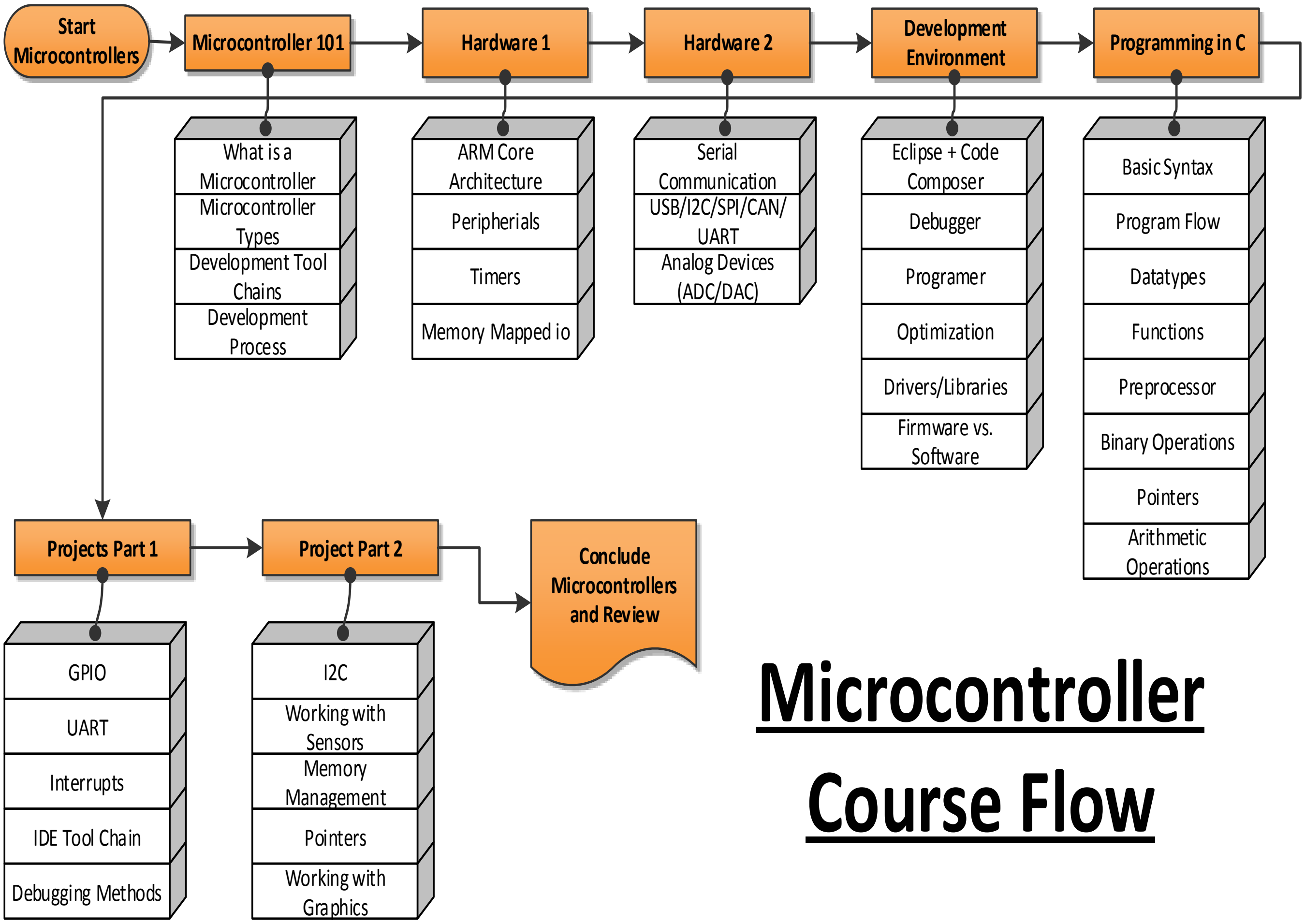

Figure 2. Microcontroller Course Flow

as those involving I2C busses and accelerometers. After teaching this for the past few years, the team has realized that there is a requirement for teaching programming languages to instructors for them to be successful. As such, a portion of each workshop is dedicated to a review of programming languages. The approach for these workshops is that they be taught by a combination of skilled university and community college instructors. By having both types of instructors presenting the workshops, it allows instructor attendees (who themselves will be from both community colleges and universities) to realize that the infusion of this type of technology is possible in their own types of school. The laboratory component of the workshop is defined using a sequence of interchangeable laboratory modules. Flexibility enables them to be tailored by individual instructors. The workshop is designed to introduce the basics of microcontroller technology to instructors. By the end of the workshop, instructors will be capable of doing simple projects and understanding microcontroller hardware and design tools. Texas Instrument's ARM microcontroller was chosen for the workshops based on the wide popularity of the ARM processor and the excellent (and free) design tools.

Hardware Development Environment: Tiva C Series TM4C123G LaunchPad Evaluation Board

The Tiva LaunchPad Evaluation Board is a low-cost evaluation platform for ARM [8] Cortex-M4F-based microcontrollers. The Tiva C Series LaunchPad design features the TM4C123GH6PMI microcontroller, providing a hardware platform to exercise the full-scale functionality that Tiva family of microcontrollers can deliver. Some features include: in-circuit-debugger, I/O headers, USB connection, RGB LED, USB-to-serial converter, and pushbuttons. Digilent has an Orbit board that provides expanded capabilities to the Tiva platform such as OLED display, expandable PMOD connectors, potentiometer, switches, pushbuttons, LEDs, and I2C headers. Figure 3 shows both the Tiva LaunchPad and the Orbit board.

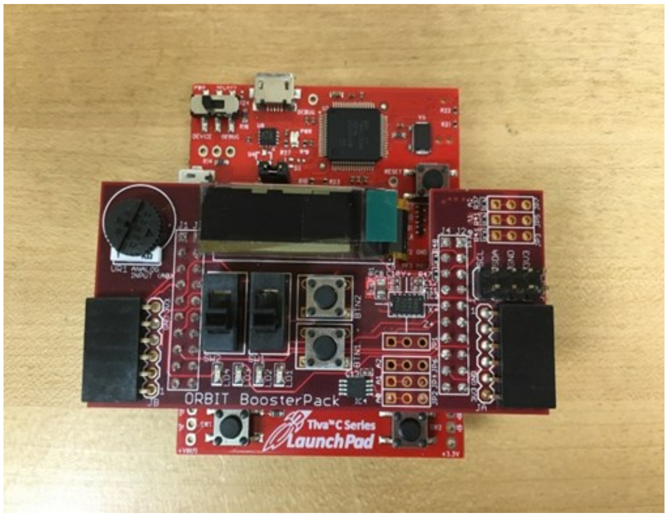

Figure 3. Tiva LaunchPad and Digilent Orbit

Hands-on Laboratory Exercises

A set of nine laboratory exercises were developed. These labs consisted of an introduction to the Tiva LaunchPad software used to code, compile, and program the Tiva TM4C (formerly Stellaris LM4F) series of ARM Cortex-M4 microcontrollers; an introduction to the basics of the C code syntax and how it is used in the TI implementation of the ARM processor; a lab focusing on the Digilent Orbit board, which provides expanded capabilities to the Tiva platform; a lab focusing on application program interface and interrupts; a lab on serial communication; a lab focusing on analog-to- digital converters; and, finally, a complete project of integrating an analog-to-digital converter with serial communication. Following is a description of each laboratory exercise.

Lab 1: Introduction to Tiva LaunchPad Software

This lab is designed to familiarize the participant with using many of the common aspects of the Tiva LaunchPad software. Participants receive sufficient instruction and guidance so that they are able to install the software and prepare for the following laboratories, where the hardware will be plugged in and a simple project will be accomplished. Participants download and install the software that will be used to perform the work associated with TI ARM-based processors utilizing the Tiva evaluation kit with the optional Digilent daughter board (Orbit).

Lab 2: Introduction to Tiva LaunchPad Evaluation Kit

This lab is designed to familiarize the participant with using many of the common aspects of the Tiva LaunchPad evaluation kit. The evaluation kit features programmable user buttons and a red, green, RGB LED for custom applications. The LaunchPad BoosterPack XL will provide a mechanism of supporting external interface to other peripherals. Participants receive sufficient instruction and information so that they are able to connect the Tiva board for the first time and create a simple project that lights an LED. Participants will be introduced to the building and debugging process within the Code Composer Studio (CCS v6) environment.

Lab 3: Blinking Lights

This lab is a continuation of lab 2 and builds upon the skills learned from previous labs. This lab helps the participant to continue to gain new skills and insight on the C code syntax and how it is used in the TI implementation of the ARM processor. Each of these labs add upon the previous labs and it is the intention of the authors that the student will build with a better understanding of the ARM processor and basic C code.

Lab 4: Digilent Orbit Board Introduction and LEDs

The goal of this lab is to continue to become familiar with the compiler and understand the use and modification of a "main.c" file. Workshop participants are also exposed to C functions. In addition, the Digilent Orbit board [9] is introduced in this lab. The Orbit was built for academic purposes for learning how to do small projects. It provides an expansion to the capabilities of the Tiva platform. The Orbit provides more LEDs, switches and buttons. This lab is very similar to the Blinking Lights lab, but it is accomplished using the Digilent Orbit board.

Lab 5: Application Program Interface (API) and Interrupts

The goal of this lab is to introduce the concepts of the API and interrupts. API is a set of routines, protocols, and tools for building software applications. A good API makes it easier to develop a program by providing all of the building blocks. The designer then integrates the building blocks, commonly referred to as a set of functions. These functions are contained on ROM inside the microcontroller. The beauty of the API functions is that they reduce the number of resources used and, thus, the amount of power consumed. This is very important for low-power applications. To use a given function, the designer needs to call the function and pass the function parameters list. Interrupt concept is also introduced in this lab.

Lab 6: UART Serial Communication

The goal of this lab is to introduce the concepts of the Universal Asynchronous Receiver/Transmitter (UART) and how it is implemented on the ARM processor. A UART is a block of circuitry that transmits data between the serial and parallel forms. They are usually paired up with communication standards like RS-232. It usually takes bytes of data and transmits them in a sequential fashion. UART modules are embedded into many microcontroller systems, including TIVA microcontrollers. The objective of this lab is not to have the participants fully understand a UART (that can be done by using Google), but rather to understand how to design a project utilizing UART on the Tiva board. Participants learn how to enable the UART port and how to configure associated pins.

Lab 7: Temperature Sensor

The goal of this lab is to introduce the temperature sensor and then the utilization of the UART to display the room temperature on the computer. The ORBIT board is equipped with Microchip Technology Inc.'s [10] TCN75A digital temperature sensor that converts temperatures between -40° C and +125°C to a digital word, with ±0.1°C accuracy. It does also have a user-programmable registers to provide more flexibility for temperature-sensing applications. Participants learn how to configure I2C. I2C is a bi-directional bus with efficient data transfer to multiple slaves. The whole process is controlled by merely two wires: a synchronous data line (SDA) and a synchronous clock line (SCL), which allows one to save space while designing any hardware system. TIVA I2C offers many functions apart from providing bi-directional data transfer through a two-wire design and interfaces to external I2C devices such as serial memory, networking devices, LCDs, and tone generators.

Lab 8: Accelerometers

The goal of this lab is to introduce the concept of the accelerometer. The ORBIT board is equipped with the ADXL345, a small, thin, ultra-low-power, 3-axis accelerometer with high resolution (13-bit) measurement capabilities [11]. The ADXL345 output data is formatted as 16-bit 2's complement and is accessible through either an SPI or I2C digital interface. The ADXL345 is well-suited platform for mobile device applications. Static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion or shock can be measured. Participants configure the I2C, read the accelerometer data, and toggle the proper LED to provide tilt measurements.

Lab 9: Capstone Project

This lab acts as a capstone to the entire ARM microcontroller workshop. This integrating experience develops participant competencies in applying technical skills in solving a design problem. It covers various topics previously discussed and adds some even more advanced techniques and algorithms. It also gives a good real-world application of what can be accomplished with microcontrollers.

Workshop Evaluation and Assessment

In any curriculum reform, assessment is a vital part; it helps provide key information for workshop continuous improvements, and determine if the workshop has met its objectives. An evaluation plan was implemented for the project that used a value-creation evaluation framework to determine the merit or worth of the project. To date, evaluation activities have measured the "Immediate Value" and "Potential Value" of the project-sponsored activities. Evaluation activities are now focusing on measuring the "Applied Value" by tracking students impacted by outreach activities and surveying educators who participated in the microcontroller workshops. The "Realized Value" produced by the project focuses on the number of students from outreach activities that enter two-year technical programs and the number of graduates from two-year technical programs who have a working knowledge of microcontroller technology.

Workshop attendees gain immediate value by participating in workshop activities. This immediate value is gained through the information presented and the activities (e.g., presentations and laboratory exercises). Immediate value is assessed through pre-workshop and post-workshop surveys. The post-workshop surveys also point to potential value; that is, the intent to integrate workshop material into the classes that they teach, or in other professional activities, if they do not teach. The applied value surveys were conducted during fall semester 2014 and spring semester 2015. The survey queried all educators who attended the microcontroller workshops since the project began. Over one-quarter of the educators who attended a workshop applied their knowledge and delivered microcontroller instruction at their institutions. During the 2014-15 academic year, these educators reported that approximately 23,000 student-hours of microcontroller instruction were delivered. This instruction in microcontroller technologies impacted 225 students in two-year colleges and 235 students at four-year institutions. Regarding immediate value, 48 faculty (25 community college instructors and 23 four-year engineering technology professors) attended the workshops. Twenty-nine out of 48 (60%) of the educators were currently teaching microcontrollers in their classes. On the other hand, for potential values, 39 out of 48 (81%) educators planned to incorporate workshop material into their classes, either during the 2015-16 academic year or the 2016-17 academic year.

Realized value is the number of potential students who actually enroll in two-year technical programs and the number of graduates from two-year technical programs who enter the technician workforce. Enrollment data and graduate information are obtained via surveys sent to partner sites and workshop participants. Table 1 summarizes the survey data for community colleges and Table 2 summarizes the survey data for four-year colleges and universities. Note: A "student-hour" of instruction equals one student receiving one hour of instruction and is computed on a class-by-class basis.

Table 1. Applied Value Survey Results for Fall Semester 2014 and Spring Semester 2015 at Community Colleges

Category (Community Colleges)	Fall 2014	Spring 2015	Total for Year
No. of Educators	6	7	13
Students Impacted	119	106	225
Instructional Hours	322	114	436
Student Hours	5,749	1,532	7,281
Gender:			
Male	100	99	199
Female	8	7	15
Ethnicity:			
Caucasian	71	87	158
Hispanic	13	8	21
Asian/Pacific Is.	7	6	13
African-American	8	3	11
Native-American	0	1	1
Other Ethnicity	9	1	10

A total of 23,000 student-hours of microcontroller instruction were delivered at the college level during the 2014-15 academic year. The number of student-hours of instruction delivered at the four-year level was double that delivered by community colleges and may reflect a greater ability to apply the technology or the need for greater depth of instruction at the four-year level. The gender data show that females were a distinct minority in microcontroller classes, and that the class was composed mainly of Caucasian students. Hispanic students and those of Asian/Pacific Islander ancestry made up a higher percentage at the four-year level than were in two-year, community college microcontroller classes.

Table 2. Applied Value Survey Results for Fall Semester 2014 and Spring Semester 2015 at Four-Year Colleges

Category (Four-Year Colleges)	Fall 2014	Spring 2015	Total for Year
No. of Educators	4	7	11
Students Impacted	127	108	235
Instructional Hours	349	372	721
Student Hours	7,419	8,301	15,720
Gender:			
Male	116	97	213
Female	11	11	22
Ethnicity:			
Caucasian	49	63	112
Hispanic	35	25	60
Asian/Pacific Is.	26	12	38
African-American	7	5	12
Native-American	0	0	0
Other Ethnicity	10	3	13

Interest in professional development workshops similar to those offered through the project seems to remain high. Registrations are adequate to fill workshops and the project continues to draw educators from across the country. To date, over 100 community college and university faculty members have been trained to provide deeper instruction to their students utilizing the modules provided during the workshops. Several thousand secondary school students have been exposed to career information about the electrical engineering technology field. Reports on the best practices developed by the project team have been disseminated through publication in related journals, through presentations at conferences, and through local workshops conducted by the team members. Students trained on the technologies discussed at the workshops will be better prepared to develop new products and push the envelope of technology evolution in the electrical engineering field.

Conclusions

Digital systems sit at the core of the technologies that most enrapture younger generations. In this paper, the authors discuss the offering of two-day ARM-based microcontroller workshops for electrical engineering technology faculty, as part of an NSF-ATE grant. Curriculum resources and workshop materials are also being made available to faculty in other electrical and computer engineering technology programs. Workshop curriculum materials are shared directly with all participants who attend the workshops, and the curriculum is also available electronically through a project website. This professional development provides both two-year and four-year electrical engineering technology faculty with the pedagogical and subject matter knowledge, digital teaching tools, and teaching strategies that will attract and effectively prepare students for STEM careers in reconfigurable electronics. Academia needs to continuously update curriculum to match industry needs, faculty professional development on latest technology in reconfigurable electronics is must to provide graduates with the up-to-date skills in re-configurable electronics design. Assessment results showed that, during the 2014-15 academic year, microcontroller workshop participants reported approximately 23,000 student-hours of microcontroller instruction. One-third of these student-hours were in two-year programs and two-thirds in four-year programs. Interest in professional development workshops similar to those offered through the project remains high. Registrations are adequate to fill workshops and the project continues to draw educators from across the country.

Acknowledgements

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Biographies

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BASSAM MATAR is a fun and challenging guy, who clearly gets things done and loves his work. He is a 24-year veteran engineering faculty member in the Maricopa Community College District. After 11 years of teaching, Bassam built the engineering program at Chandler/Gilbert Community College, where he still works. He developed courses, articulated with surrounding universities, led committees, met with industry leaders, organized events, attended conferences, and applied for grants to enhance the program for students. More specifically, his career includes service as PI or Co-PI on eight National Science Foundation-funded grants. In addition, he has been a lecturer at Arizona State University for 12 years. All of the effort and collaboration has amounted to a well-established Chandler/Gilbert Engineering Program—the largest in the district. Recognitions and awards include Motorola Educator of the Year Award, the National Institute for Staff and Organizational Development Award, the 2010 Electronic Engineering Times ACE Award Educator of the Year, and the City of Gilbert Community Excellence Award for Educator of the Year. Mr. Matar may be reached at b.matar@cgc.edu

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CLOUD-BASED MOBILE APPLICATIONS IN ENGINEERING DRAWING EDUCATION

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Abstract

Some students encounter difficulty in imagining necessary orthographic views in order to analyze engineering drawing problems. The aim of this study was the design of cloud-based interactive applications with new technologies to supplement traditional teaching methods in engineering education. Mobile technologies have been growing rapidly in recent years and play an important role in our everyday lives. The universality of mobile devices opens up new opportunities for developing applications for education. Research has shown that smartphones extend the opportunities and efficiency of engineering education because of ease of accessibility and portability. The interactivity and effectiveness of smartphones in classroom instruction will get even broader if cloud-based applications are used. Cloud-based mobile applications will be changing the visualization channels, too. Three-dimensional displays will be replacing two-dimensional monitors in the future as they get more and more economical and accessible.

In this paper, the author describes efforts to use 3D mobile viewers in an engineering drawing class to enhance the interest, engagement, and spatial cognition of students. A cloud-based service was used to deploy the 3D stereoscopic virtual models. Smartphones and Google Cardboard were used to display the 3D stereoscopic models. Cloud-based applications were used to integrate it with CourseWeb in order to enable students to use their own devices.

Introduction

Cloud computing is a service concept and defined by the National Institute of Standards and Technology (NIST) as "a distributed computing architecture that enables access to virtualized resources including computers, networks, storage, development platforms, or applications." It is a system for global access to shared resources of computers and servers. [1] This system depends on the cloud provider that shares the resources that are needed by individual computers or devices, with minimal interaction with the user [2], similar to a utility service (like the power grid) over a network [3]. Cloud services have become involved in everyday tools such as mail, file storage, or mobile applications, and no software developer can imagine an application without cloud computing anymore.

In the NMC Horizon Report 2016, trends and drivers for educational change are searched and the use of cloud-based technologies are recognized as a key trend, while "redesigning learning spaces in technology-enhanced learning (TEL) domains" [4]. Educational institutions change their settings by designing learning environments to facilitate "emerging pedagogies and strategies, such as the flipped classroom and to support project-based interactions with attention to greater mobility, flexibility, and multiple device usage" [5]. In the flipped-classroom approach, the lecture and homework components are in a different order. Students learn at home before coming to class and use this knowledge to spend more time on exercises or projects during class time. Students are more flexible, active, and more engaged with this method, if it is used with technology blended and inquiry-based learning approaches [6]. Another practice at campuses all across the world is Bring Your Own Device (BYOD) [7]. Students are taking their own laptops, smartphones, or other devices with them to classrooms and using them to enhance their learning experiences. Students are encouraged to use mobile devices for personal and learning needs on campus. According to a recent student study [8], 86% of students enter the classroom with their own devices. Even though the majority of students carry their own smart devices, not all do. This can be a disadvantage. Another disadvantage can involve health issues such as nausea and headaches from prolonged use of 3D stereoscopic viewers.

Cloud computing provides the necessary platform to give e-learning services to students for their mobile devices. Three main types of cloud-based services are available for software developers: i) Infrastructure as a Service (IaaS), ii) Platform as a Service (PaaS), and iii) Software as a Service (SaaS) [9]. They are implemented at different levels. IaaS offers the user data processing, storage, networking, and computing capabilities on-demand. App engines are examples of PaaS and provide software programing and runtime environments to the user. Applications are easy to create and maintain with programming languages such as Python, Java, Go, and PHP. It is not necessary to maintain any servers with PaaS. The last category, SaaS, refers to providing on-demand applications over the Internet. Providers offer their applications using SaaS over the network, as an alternative to being installed and run on the user's computer or device. For example, Autodesk Fusion 360 [10] is a cloud-based CAD/CAM system for product design and includes a combination of functions such as product design, team collaboration, and part machining. Most CAD systems utilize cloud services such as A360 [11], 3DEXPERIENCE [12], and PTC PLM Cloud [13]. Other SaaS providers also offer platforms to run any software in a network browser [14] with any device; such cloud-based services have recently emerged as a compelling standard for managing and delivering applications over the Internet [15].

Many students without visualization skills cannot imagine the engineering problems and encounter difficulty in figuring out necessary views in order to solve problems. In this study, cloud-based mobile applications were utilized to open new visualization opportunities to students. In this paper, the author describes efforts to use 3D mobile viewers in an engineering drawing course in order to enhance the interest, engagement, and spatial cognition skills of students. To this end, a cloud-based service was used to deploy the 3D stereoscopic virtual models. Smartphones and Google Cardboard were used to display the 3D stereoscopic models.

Flipped-Learning and Technology-Blended Classroom for Engineering Drawing

Student success in first-year engineering drawing classes is dependent on the student's ability to mentally construct three-dimensional (3D) models based on two-dimensional (2D) sketches. ET0011 Engineering Drawing is a required course at the University of Pittsburgh at Johnstown (UPJ) that is offered for freshmen with learning objectives such as interpret and communicate with technical drawings, use of CAD systems, and understand and apply technical drawing standards. After the course, students are expected to have the visualization, software, and technical skills to deal with technical problems. A cloud-based system with lecture slides and videos was created to support the flipped learning. 3D virtual models for smartphones with Google Cardboard viewer was developed and deployed in CourseWeb to facilitate the visualization.

Flipped learning is a technique in education that provides a new flexible form of learning to the new generation that grows up with information technology. In flipped learning, students learn the new content outside of the classroom using online educational resources just before coming to the classroom. In our case, it was made possible with online video tutorials, lecture slides, and using massive open online courses (MOOC). Figure 1 shows that, by having lectures available online, students are able to go back and review topics that they might not fully understand. Students prepare to participate in class activities, while practicing how to apply key concepts with the lecturer's feedback during classes. Students are able to spend more time developing strategies for creating robust models with simple modeling technics and asking questions to get answers for the fundamental concepts.

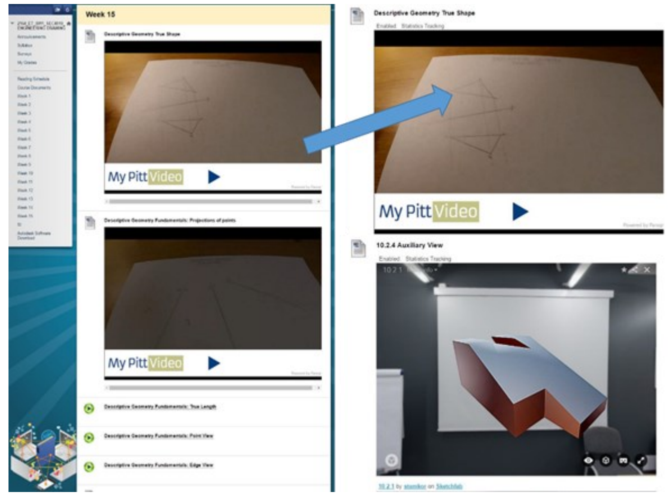

Figure 1. Online Tutorials Made Available on CourseWeb

Designing a Cloud-Based Learning System to Support Visualization Skills

The concepts of descriptive geometry and projection views challenge most students. Figure 2 shows how some students encounter difficulty in generating necessary projection views of the technical detail in order to solve the problems, while analyzing various projection views. Engineering students need geometry visualization skills, because visualization is the first step for spatial cognition of problems. Conceptual objects need to be pictured before geometric thinking and graphic representation of conceptual product ideas. Many students without visualization skills cannot imagine the engineering problems assigned to them. However, these skills can be improved by learning the interpretations of the representations and reasoning.

Students need to mentally construct a 3D image of a part based on two projection views with incomplete information. Many students lacking this skillset cannot comprehend the engineering problems assigned to them during class time [16]. The overall benefits of the virtual models in spatial visualization training have been observed and reported in the literature [17-19]. Student's spatial skills are measured by standard tests. Several studies have been published on spatial skills and its correlation with student success in engineering education [20-23]. The students in ET0011 were pre - and post-tested with the standard mental rotation tests [24]. Tests were given at the beginning and at the end of each semester. Some of the students benefited more than others from learning activities that were supported by mixed -reality (MR) mobile apps.

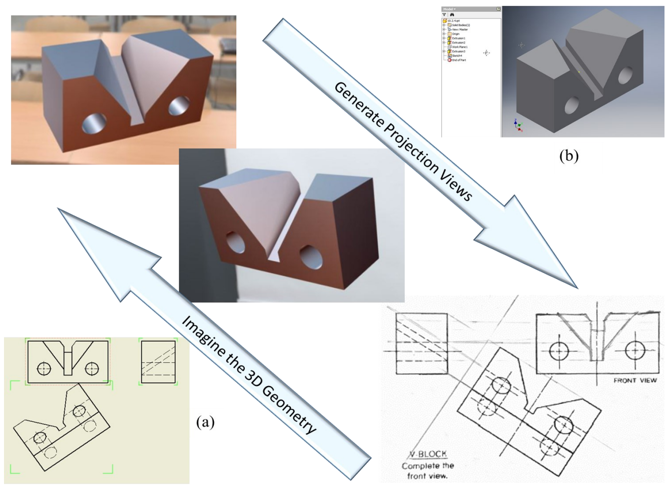

Figure 2. Mental Translations: (a) from Projection Views to 3D Object Model and (b) from 3D Object Model to Projection Views

Preliminary results for fall 2014, 2015, and spring 2016 terms indicated an improvement of 20% between pre- and post-MRT scores after both traditional and MR-enhanced training [25]. The author also observed that spatial visualization comes naturally for most students, but some cannot comprehend the engineering problems assigned to them. Several models of technical components were used in the classroom to improve design and visualization skills. Students experienced different types of learning activities (real physical/foam model, CAD model on 2D screen, and stereoscopic 3D models) during the semester, and benefited on different levels based on their preferences and abilities. In order to understand and analyze the effects of the stereoscopic 3D models and proposed mobile technology in the solution of an engineering drawing problem, auxiliary view and descriptive geometry topics were chosen for further study.

Technological visualization aids for different students with different learning needs were provided from physical prototypes to digital computer models. GeoVIS (Geometry Visual Learning System) is another visualization tool. It was developed as an MR mobile app and projects the virtual model in front of the students' eyes, allowing them to see the 3D representation of the objects in the problems. This generates an immersive experience, similar to giving a real model of the problem to each individual student, which is not always possible in large classes. The augmentation of 3D digital models of existing paper-based engineering graphics problems helps students to picture the most difficult task with their unexperienced eyes.

3D virtual models were deployed to a cloud service called Sketchfab. Figure 3 shows how students were able to download different types of virtual models from CourseWeb and run the GeoVIS directly on their smartphones with a Google Cardboard.

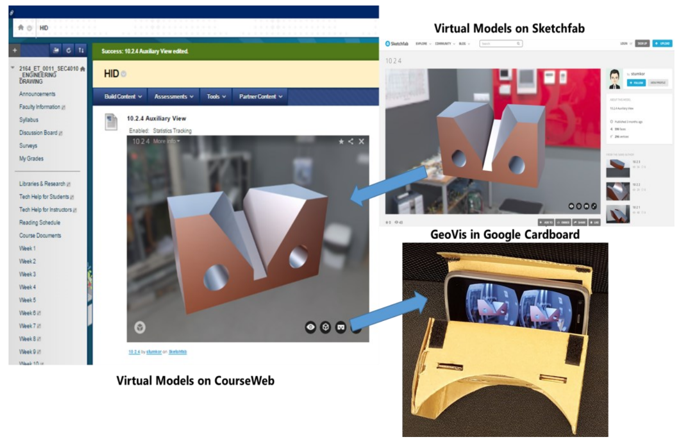

Figure 3. 3D Virtual Models

Virtual models are controlled by head movements and also by using a wireless controller. Figure 4 shows how this system projects two views of the CAD model on each half of the screen, which, when perceived by the eye through the pair of biconvex lenses, creates an augmented stereoscopic model.

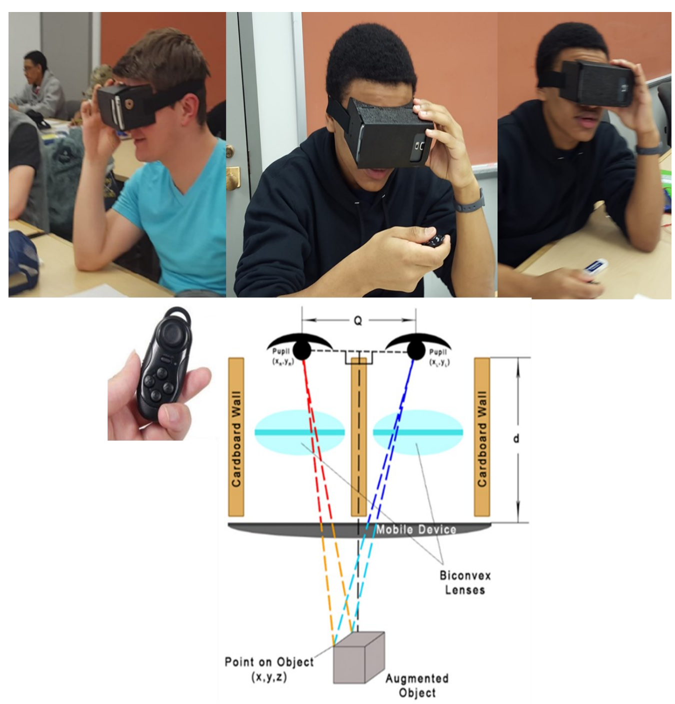

Figure 4. Google Cardboard Display of a Stereoscopic View of the Virtual Model

In this study, four problems were assigned to students after a brief lecture about the projection views, while especially focusing on the auxiliary view. Students were asked to complete missing views on the given handouts. Figure 5 shows how students can interact with the 3D model by virtually touching and rotating it to observe before and after sketching the missing view. The auxiliary view is a special orthographic view that is projected into a plane that shows the true shape of the feature that does not lie in one of the principle planes. This may be a challenge for most of the students not having a notion of descriptive geometry.

ET011 had two sections with 58 students in fall 2015. The first section (group A) used GeoVIS in class after the lecture. Students in this group went inside the virtual rooms and interacted with the virtual models before the assignment.

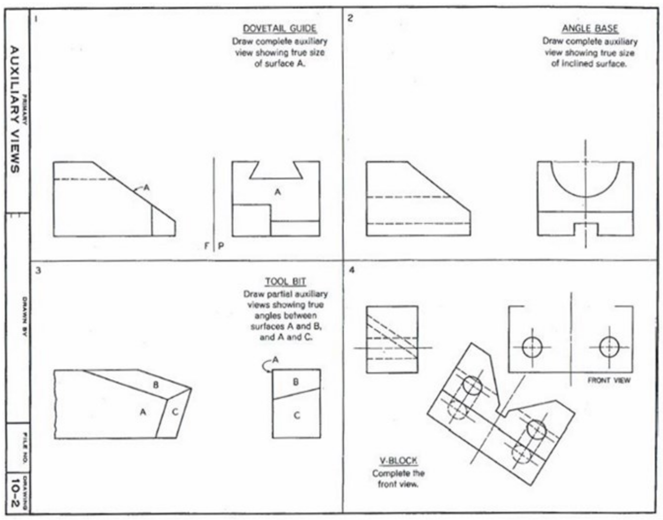

Figure 5. Auxiliary View Test

Figure 6 shows how the other section (group B, the control group) completed the exercise just after the conventional lecture, without using any virtual models. Students in both groups attempted the same test questions. Student success rate in group A was higher compared to group B. Means of the auxiliary tests performance were calculated for all students in both sections.

A paired sample t-test was conducted to evaluate whether a statistically significant difference existed between the mean achievement scores with and without the use of GeoVIS before the auxiliary view assignment. Only the scores of 46 participants that fully participated were included in this study. The results of the paired sample t-test revealed that the results were significant: $t(34)=(-6.23)$, $p\leq 0.05$, for the first question and $t(30)=(-8.98)$, $p\leq 0.05$, for the second question. Effect size was medium to large, based on Cohen's conventions [26]. Table 1 shows that the mean difference between the two groups was significant (95% confidence interval). The students who had difficulties on the 2D projection views benefited more from the MR or VR experience, which provided them with 360-degree visualization of the parts that needed to be mentally pictured before drawing. In order to see the level of understanding and abilities of the students in the two groups, they were tested with the same questions again after one week of training, but this time both groups used the same online material, additional video tutorials, and GeoVIS. Means of the auxiliary tests performance were calculated for all students in the two classes.

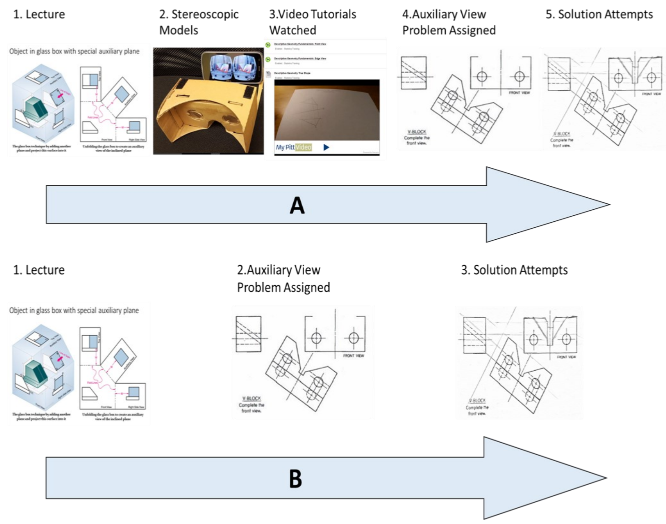

Figure 6. Auxillary View Test in Two Groups

Table 1. Means of the Auxiliary Test Scores

	Sample Size	First attempt %		Second attempt %	
		1st Question	2nd Question	1st Question	2nd Question
Group A	21	78.41	40.93	97.12	85.86
Group B	28	60.89	34.94	92.95	82.41
Difference%	N/A	28.77	17.14	4.49	4.18

Conclusion

In this study, a flipped-learning and technology-blended classroom for an engineering drawing course was evaluated. A cloud-based mobile application for Google Cardboard was created that augmented 3D digital models of paper-based engineering graphics problems. These applications were used by freshmen in engineering education as a learning tool to enhance their 3D visualization. Students were either granted access to the MR application called GeoVIS or not. In order to understand and analyze the effects of this technology as a visualization aid, an auxiliary view problem in the descriptive geometry context was chosen. Two possible treatments were analyzed. Those given access were compared to those who were not given access to the application. Their test score results for two auxiliary view questions were analyzed. The analysis results revealed that the students developed better visualization skills and got 17-29% better scores after using GeoVIS.

Acknowledgments

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Biography

SERDAR TUMKOR is an assistant professor of mechanical engineering at the University of Pittsburgh at Johnstown. Dr. Tumkor has more than 20 years' of experience in education, having taught at Stevens Institute of Technology and Istanbul Technical University. His engineering experience includes design, manufacturing, and product development. Dr. Tumkor may be reached at tumkor@pitt.edu

A TEMPERATURE ALARMING SYSTEM BASED ON AN HCS12 MICROCONTROLLER

Caiwen Ding, Syracuse University; Yuqiu You, Ohio University

Abstract

Temperature monitoring and control is critical in many production systems. In this paper, the authors present a project in which a temperature alarming system was designed, built, programmed, and tested, based on an HCS12 microcontroller. The device was composed of a temperature detector chip (LM35DT), an Axiom CMD-12DP512 board with an HCS12 microcontroller, and LEDs with two SN74LS47 chips for data display. The LM35DT detector detects temperature and sends the voltage signal to the HCS12 microcontroller. The HCS12 microcontroller is a typical data processing system. The ADC module converts the signal to digital so that the microcontroller can process and compare the information. The temperature signal is sent to the display device in order to provide a digital temperature display. In this paper, the authors examine the hardware components and programming of such a temperature-sensing system, explain the operation, and analyze the performance.

Introduction

Temperature is an important parameter to be monitored and controlled in many production systems, including process control and discrete control systems. An efficient, accurate, and cost-effective temperature control system is required for production systems in which temperature needs to be monitored and/or controlled. The performance of a temperature monitoring and control system is based on the performance of detecting a device, data processing, data conversion, and data display.

The purpose of this research project was to design, build, and evaluate a real-time cost-effective temperature alarming system, based on an HCS12 microcontroller. The device was made up of a temperature detector chip (LM35DT), an Axiom CMD-12DP512 board with an HCS12 microcontroller, and LEDs with two SN74LS47 chips for data display. The LM35DT detector detects temperature and sends the voltage signal to the HCS12 microcontroller. The HCS12 microcontroller is a typical data processing system. The HCS12 reduces interrupt latency and has high performance, instructions are executed faster, while remaining deterministic [1]. The ADC module converts the signal to digital so that the microcontroller can process and compare the information. The temperature signal will also be sent to the display device to provide a digital temperature display. When the temperature reaches a predetermined level, an alarm signal is sent to the LEDs. The performance of the system is evaluated based on response time, accuracy, and control range.

System Overview

The temperature alarming system is composed of a temperature detector chip (LM35DT), an Axiom CMD-12DP512 board with an HCS12 microcontroller, and LEDs with two SN74LS47 chips for data display. Figure 1 shows the structure of the system. The HCS12 microcontroller is the main component of the system and provides data processing and data flow control to other components. Table 1 lists all of the hardware components used in this project.

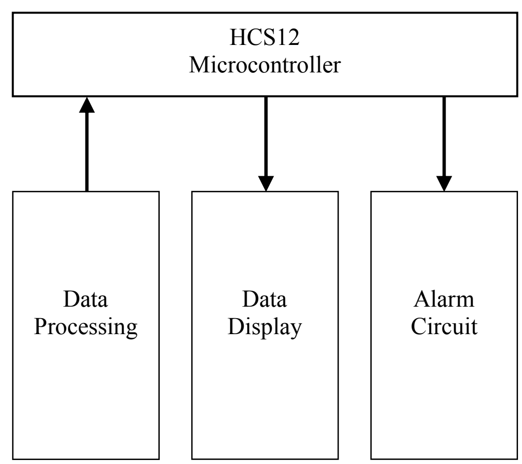

Figure 1. System Scheme

Table 1. Hardware Components

Type	Quantity(unit)
LEDs light	8
7-segment LED	2
LM35DT	1
Axiom's CMD-12DP512	1
SN74LS47	2
Wires	As needed

The system is setup by wiring the LM35DT temperature detector and the LEDs with two SN74LS47 chips to the HCS12 microcontroller using wires and a breadboard. Figure 2 shows the wiring schematic of the connection between an SN74LS47 chip and a 7-segment LED. Figure 3 illustrates the entire wiring schematic for the system.

The flowchart of the programming design is shown in Figure 4. The main procedures include system initialization for temperature detecting, A/D conversion of the analog temperature signal, temperature displaying, comparing, and setting up of the alarm. The critical parts of the project's programs are A/D conversion and temperature display, which are discussed in detail in the following sections.

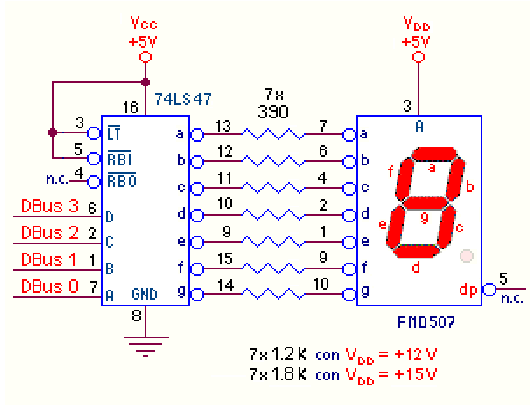

Figure 2. Connection of a 7-segment LED Display with an SN74LS47 IC

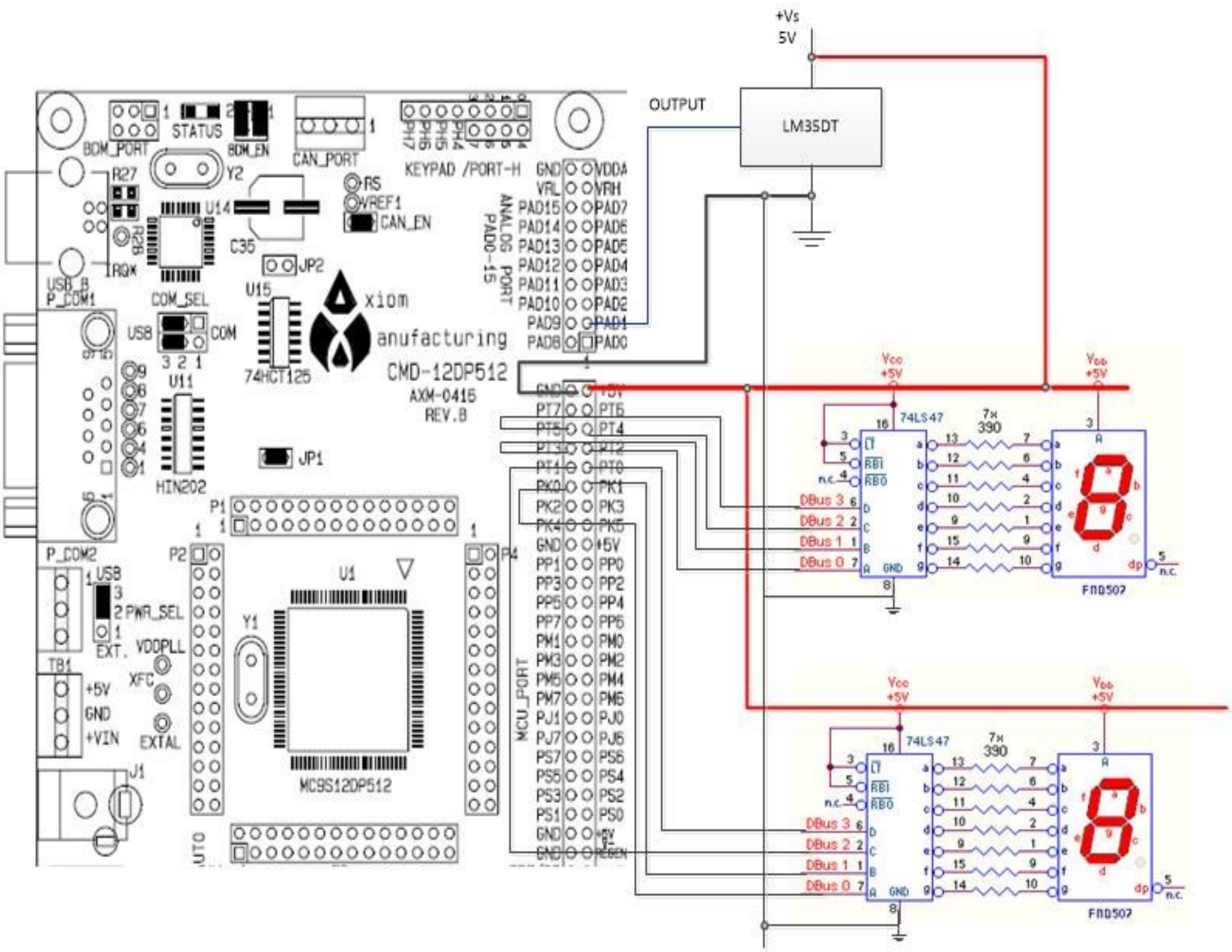

Figure 3. System Wiring Schematics

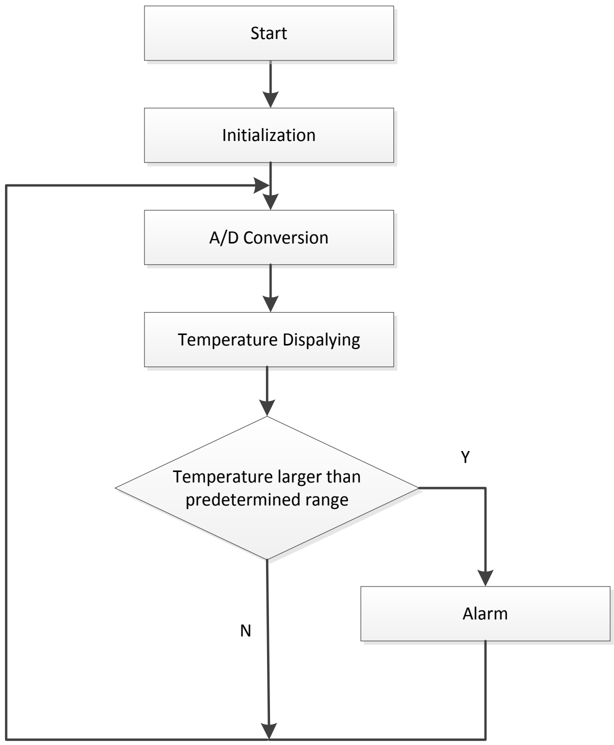

Figure 4. Flowchart of the Programming Design

Method and Programming of A/D Conversion

A/D conversion is the most critical procedure in this system and is performed by an ADC module on the HCS12 microcontroller. The HCS12 ADC module is highly autonomous with an array of flexible conversion sequences. These conversion sequences need to be programmed so that the analog source starts the conversion, the number of conversions to be performed are noted, and the multiple input channels can be indicated. Conversion sequences can also be repeated continuously without the MCU overhead. Sequences can be started by a write to a single register or by a valid signal on an external trigger input (to synchronize the ADC conversion process with external events). For each conversion in the sequence, the sample time, conversion resolution, and data format need to be specified in the program.

The ADC module has a 2 MHz module clock, so that it can perform an 8-bit single sample in 6 µs. This module does not need any external circuits for sampling or data storage. An internal sample buffer amplifier minimizes the effect of this charge sharing between consecutive conversions [2, 3].

Figure 5 shows the functional block diagram of the ADC module. This ADC module is made up of an analog subsystem and a digital control subsystem.

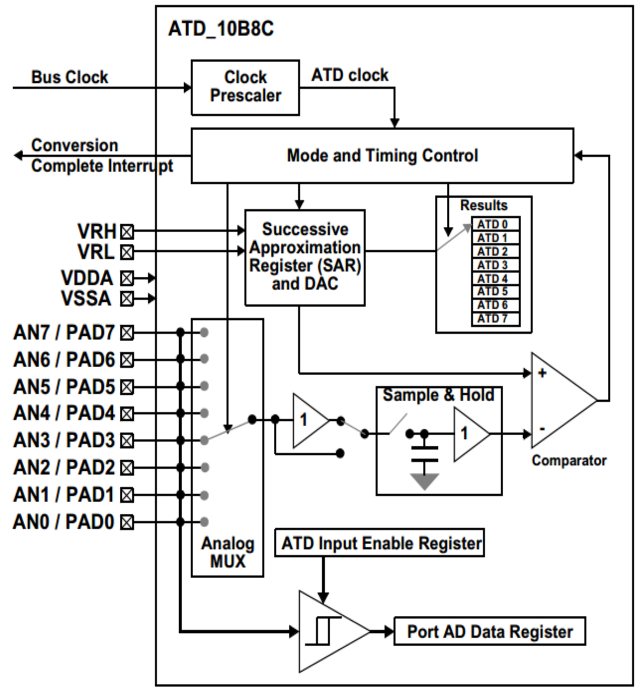

Figure 5. Block Diagram of the ADC Module

The analog subsystem has several components: multiplexer, input sample amplifier, resistor-capacitor digital-to-analog converter array (RC DAC), and high-gain comparator. It functions as follows: the multiplexer selects a signal for conversion, either one of three internal or one of the external signal sources. The sample amplifier then precharges the sample capacitor before connecting it to the input potential. The digital-to-analog comparison output necessary for successive approximation conversion is provided by the RC DAC; the comparator indicates whether the RC DAC array successive output is higher or lower than the sample. The conversion process and sequences are controlled by a digital control subsystem, which contains registers and logic sequences [4].

This ADC module uses successive approximation architecture to perform the analog-to-digital conversion. The resolution of the ADC module is selectable as either 8 or 10 bits. It functions by comparing the saved analog sample potential on the sample capacitor with a series of digitally generated analog potentials. The converter finds the closest potential to the sampled signal by running a binary search algorithm. The closest potential then is sent to the successive approximation register (SAR), and is stored in the digital format specified in the conversion sequence program.

The A/D conversion is programmed and configured to be completed with six steps in this project, as follows:

Step 1: ADC power up. ATDCTL2 (ADC ConTroL register 2, $0062) contains several initialization parameters. Of primary importance is the ADPU bit (ADC power up bit), which must be set to one in order to power up the ADC, and the AFFC (A/D fast flag clear all) bit, which controls how A/D flags are cleared (use of the default is recommended). For example, writing $80 to ATDCTL2 will power up the ADC. After power-up, a 100 μsec. delay is required before using the ADC. This delay will allow all analog circuits to be stabilized.

Step 2: Determine the sampling and conversion time. The sampling and conversion time can be controlled with the ATDCTL4 ($0064). For normal conversions, default values should be used. If high-impedance sources are used, a longer sample time is required. For normal situations, no action needs to be taken in this step.

Step 3: Set the ATDCTL5. The ATDCTL5 register ($0065) controls the sampling methods.

- S8CM – allows 4 or 8 A/D conversions at a given time
- SCAN – set for either a single scan sequence (0) or a continuous scan sequence (1)
- MULT – set to allow conversion of a single channel (0) or multiple channels (1)
- CD-CA – selects the channel for conversion (when MULT=0)

In this project, the 8-channel mode was selected. The conversion sequences were enabled for continuous channel scan and multichannel scan. Table 2 provides detailed information of the ADC's conversion channel setup.

Step 5: A/D operation. The ATDCTL5 register is the starting register to control A/D conversion. Writing to this register starts a new conversion sequence. Once the conversion sequence is complete, a sequence complete flag (SCF) is set, after which the result is ready. Then the ADC module writes to the ATDCTL5 register, either to start a new conversion sequence or to repeat the previous sequence.

Step 6: Fetch digital results. The digital results are fetched from the ADR0H to ADR7H registers ($0070 to $007E). The conversion is completed when the SCF flag is set in the ATDSTAT register.

In conclusion, the A/D conversion procedures are: 1) power up the ADC by setting the ADPU bit in ATDCTL2; 2) wait for 100 μsec.; 3) choose the S8CM, SCAN, MULT, and CD-CA bits in the ATDCTL5; 4) write to the ATDCTL5 to start the conversion; 5) wait for the conversion sequence to complete by polling the SCF bit in ATDSTAT; and, 6) read the result in the ADR0H-ADR7H register. The program coding for the ADC module setup is as follows:

```
ATD0CTL2=0x80;
//1000 0000
//Bit 7 ADPU=1, ATD power-up
//Bit 6 AFFC=0, Fast flag clearing
 //Bit 5 AWAI=0, ATD continues to run in //wait //mode
//Bit 4,3 ETRIGLE/ETRIGP=00, External //trigger //
sensitivity falling edge
//Bit 2 ETRIGE=0, External trigger - //disabled
//Bit 1 ASCIE=0,
 //Bit 0 ASCF=0
// DELAY20uS();
 ATD0CTL3=0x08; //0010 0000
 //Bit 7,0

 //Bit6- Bit3,0001. Number of conversion per //sequence
 //S8C,S4C,S2C,S1C=0100

 //Bit2=1, FIFO=0,
 //Bit1-bit0=10, FRZ1-FRZ0, 00 = continue //conversions
 // 10 = Finish current conversion, then //freeze
 ATD0CTL4=0xE3; //1110 0111
 //Bit 7 resolution selected SRES8=1 for 8 bit //resolution
 //Bit 6 - 5, sample time select=11 for //16 A/D //conversion
clock
ATD0CTL5=0x82;
```

LM35DT Sensor and Linear Method

The LM35DT sensor used in this study was a precision temperature sensor. The sensor was calibrated directly in centigrade with a full range, -55°C to 150°C. Two different methods can be applied in converting the binary data received from the ADC to the temperature display format [5]. The first is the look-up table method, which corresponds to the real temperature, but it requires much more memory. The second one is linearizing. Linearizing translates the binary data to a real temperature display by setting up a functional relationship between them. It is easier to set up and has low memory requirements. The accuracy from the linear method is not as high as the look-up table method, but it satisfies the requirement for this project based on the existing hardware. Therefore, the linear method was selected for temperature display in this project.

By using two 7-segment LED displays and two SN74LS47 chips, the temperature can be displayed. The output pin of the ADC was PAD2. Making PORTB PIN 0~7 an alarm output, when the display data was over 80°C. Eight of the LEDs would work as an alarm signal.

Table 2. ADC Conversion Channel Setup

S8CM	MULT	CD	CC	CB	CA	Channels Converted	Result Registers	Comments
0	0	0	0	0	0	0	ADR0-ADR3	Sequence of 4
0	0	0	0	0	1	1	ADR0-ADR3	conversions of
0	0	0	0	1	0	2	ADR0-ADR3	a single channel
0	0	0	0	1	1	3	ADR0-ADR3	
0	0	0	1	0	0	4	ADR0-ADR3	
0	0	0	1	0	1	5	ADR0-ADR3	
0	0	0	1	1	0	6	ADR0-ADR3	
0	0	0	1	1	1	7	ADR0-ADR3	
0	1	0	0	x	x	0-3	ADR0-ADR3	Sequence of 4
0	1	0	1	x	x	4-7	ADR0-ADR3	conversion of 4
								Channels
0	x	1	0	x	x	Reserved		
0	0	1	1	0	0	Vrh	ADR0-ADR3	4 conversions of
0	0	1	1	0	1	Vrl	ADR0-ADR3	Vrh, Vrl, etc.
0	0	1	1	1	0	(Vrh-Vrl)/2	ADR0-ADR3	
0	0	1	1	1	1	Reserved		
1	0	0	0	0	0	0	ADR0-ADR7	Sequence of 8
1	0	0	0	0	1	1	ADR0-ADR7	conversions of
1	0	0	0	1	0	2	ADR0-ADR7	a single channel
1	0	0	0	1	1	3	ADR0-ADR7	
1	0	0	1	0	0	4	ADR0-ADR7	
1	0	0	1	0	1	5	ADR0-ADR7	
1	0	0	1	1	0	6	ADR0-ADR7	
1	0	0	1	1	1	7	ADR0-ADR7	
1	1	0	x	x	x	0-7	ADR0-ADR7	Sequence of 8
								conversions of 8 chls
1	x	1	0	x	x	Reserved		
1	0	1	1	0	0	Vrh	ADR0-ADR7	8 conversions of
1	0	1	1	0	1	Vrl	ADR0-ADR7	Vrh, Vrl, etc.
1	0	1	1	1	0	(Vrh-Vrl)/2	ADR0-ADR7	
1	x	1	1	1	1	Reserved		
1	1	1	x	x	x	Reserved		

Figure 5 shows that the room temperature can be displayed on two 7-segment LED displays. Figure 5 also shows all of the components used. Also, the ice temperature and finger temperature can be displayed.

Conclusion

In this project, the authors designed and constructed a temperature alarming system based on an HCS12 microcontroller. The procedure included data retrieval, A/D conversion, data processing using a linear method, data display design, and system testing. The hardware configuration and software programming was successful, and the system was able to detect temperature accurately and send out temperature alarm signals when the temperature reached the predetermined value. This project provides an example of system design, programming, and configuration for an application of the HCS12 microcontroller. The results can be applied in industrial environments and academic laboratories.

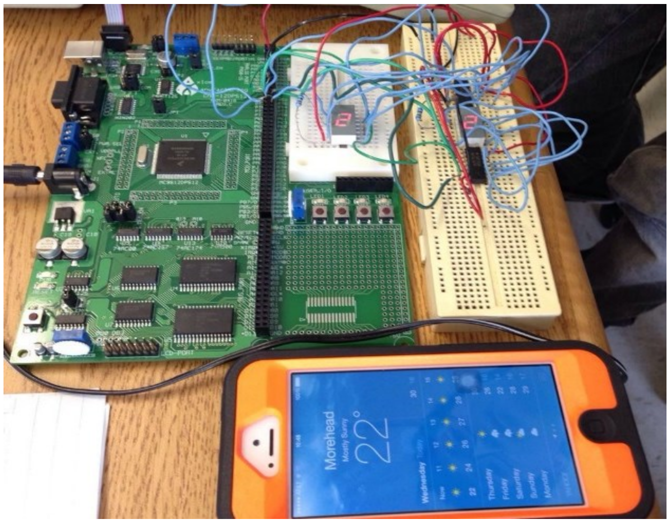

Figure 5. Testing of the System

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Appendix: Program Code (in C language)

```
#include <hidef.h> /* common defines and macros */
#include "derivative.h" /* derivative-specific definitions */
void DELAY20uS(void);
void TDELAY(void) ;
unsigned int binbyte,x,d1,d2,d3,d4,d0;
void main(void)
{
 DDRT=0xFF;
 ATD0CTL2=0x80; //1000 0000
   //Bit 7 ADPU=1, ATD power-up
   //Bit 6 AFFC=0, Fast flag clearing
   //Bit 5 AWAI=0, ATD continues to run in //wait //mode
                                //Bit 4,3 ETRIGLE/ETRIGP=00, Exter-
                         nal //trigger //sensitivity falling edge
                                //Bit 2 ETRIGE=0, External trigger - //
                         disabled
   //Bit 1 ASCIE=0,
   //Bit 0 ASCF=0
 DELAY20uS();
 ATD0CTL3=0x08; //0010 0000
   //Bit 7,0
   //Bit6- Bit3,0001. Number of conversion per //sequence
   //S8C,S4C,S2C,S1C=0100
   //Bit2=1, FIFO=0,
   //Bit1-bit0=10, FRZ1-FRZ0, 00 = continue //conversions
   // 10 = Finish current conversion, then //freeze
 ATD0CTL4=0xE3; //1110 0111
   //Bit 7 resolution selected SRES8=1 for 8 bit //resolution
   //Bit 6 - 5, sample time select=11 for 16 A/D //conversion clock
 ATD0CTL5=0x82;
 for(;;)
 {
            while (!(ATD0STAT0 & ATD0STAT0_SCF_MASK));
 DDRT=0xFF;
 d0 = ATD0DR0L;
 binbyte=d0*2+4;
 d1= binbyte % 10;
 d2=binbyte / 10;
 d3=d2*16+d1;
 PTT=d3;
 TDELAY();
 }
}
void DELAY20uS(void)
{
 int x=40;
 while(x--);
}
void TDELAY(void)
{
int x=0;
while(--x);
```

APPLICATIONS OF DIGITAL MANUFACTURING IN MANUFACTURING PROCESS SUPPORT

Vukica Jovanovic, Old Dominion University; Mihael Debevec, University of Ljubljana; Niko Herakovic, University of Ljubljana; Alok Verma, Old Dominion University; Mileta M. Tomovic, Old Dominion University

Abstract

In this study, the authors developed three new approaches and models for improvements related to manufacturing processes. The main focus was on planning in a digital environment before the actual manufacturing process is carried out. The first approach is digital manufacturing, which gives affords the opportunity for performing an entire manufacturing process in a virtual environment. In this way, engineers virtually define, plan, create, monitor, and control all production processes. The planning phase can be done simultaneously, while other manufacturing processes are already in place. In this way, processes can continue with no interruption. Various product lifecycle management tools have databases of various programs that are used for interfacing and communication with machinery, such as CNC machines and industrial robots. Ideally, after the manufacturing process has been verified in the digital environment, control data can be uploaded to numerically controlled machinery so that the production process can start. Two special models have been developed for more detailed insight into special types of manufacturing processes. The second approach represents a model for the unique type of production that takes into account all resources as the most important factor in the manufacturing processes. The main variables that were included in this model were the availability and the presence of all required manufacturing resources needed for every single manufacturing operation. The third approach represents a model for large-scale production that includes all significant parameters of a manufacturing process, as well as all required intermediate storage. The last two models were developed as parametric, and the users in the training process can easily make tests for different types of input data.

Introduction

Manufacturing process analysis is necessary for manufacturing companies to improve market competition [1]. The digital environment is used for student and workforce training. Various studies in the field of engineering education have proven that training is very effective with the use of the dynamic control of manufacturing process, where participants compare a simulation of the manufacturing process in the digital environment to the given set of parameters and the output [2]. In this current study, the digital manufacturing models proved to be a very useful tool for the training of the planners of production processes and for training and educating the mechanical engineering students. The use of the digital manufacturing models is suitable for designing new production systems or improving the existing ones [3]. A major advantage of the concepts is that the digital manufacturing models do not consume any materials, resources or energy; they operate only with data. As well, during the training process, the production process is not interrupted and, consequently, the equipment is not occupied and cannot be damaged [4].

Based on the findings of this study, two special concepts and models were developed that were shown to be useful for training during different levels of production. Manufacturing is a complex system that contains sets of tasks, materials, resources (including human resources, facilities, and software), products, and data [1]. Frequently, because of the intricacy of practical problems in manufacturing process management, their mutual interdependencies can lead to a mathematical model that is too complex to be solved by typical analytical methods [5]. For the purposes of detailed insight into special types of manufacturing processes, two models were developed: a model for unique type of production (UTP) and a model for large-scale production (LSP).

Model for Unique Type of Production

The concept for the model of a unique type of production treats operation as the elementary unit of the production process. The concept includes a logical rule that states that every single operation can be performed only when all of the required resources, the data sets, and the materials are available and present at the place of the operation being performed [6]. The sequence of operations representing the production process is shown in Figure 1.

The production process model for UTP, besides data, has the presence of resources taken into account, due to the unavailability of resources, where deadlocks frequently occur. Among the most important resources are counted transportation equipment, clamping equipment, cutting tools, measuring devices, machining centers, special tools and equipment, and human resources. Based on the logic model (see Figure 1), a simulation model of the production process for

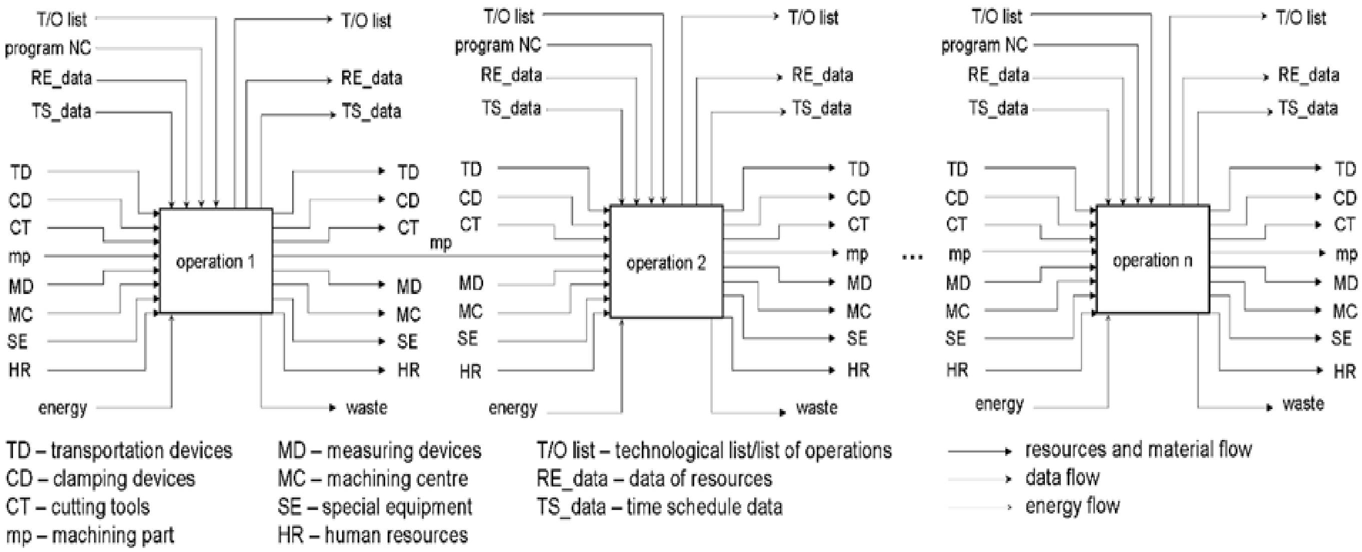

Figure 1. The Logical Scheme of the Simulation Model for a Unique Type of Production [7, 8]

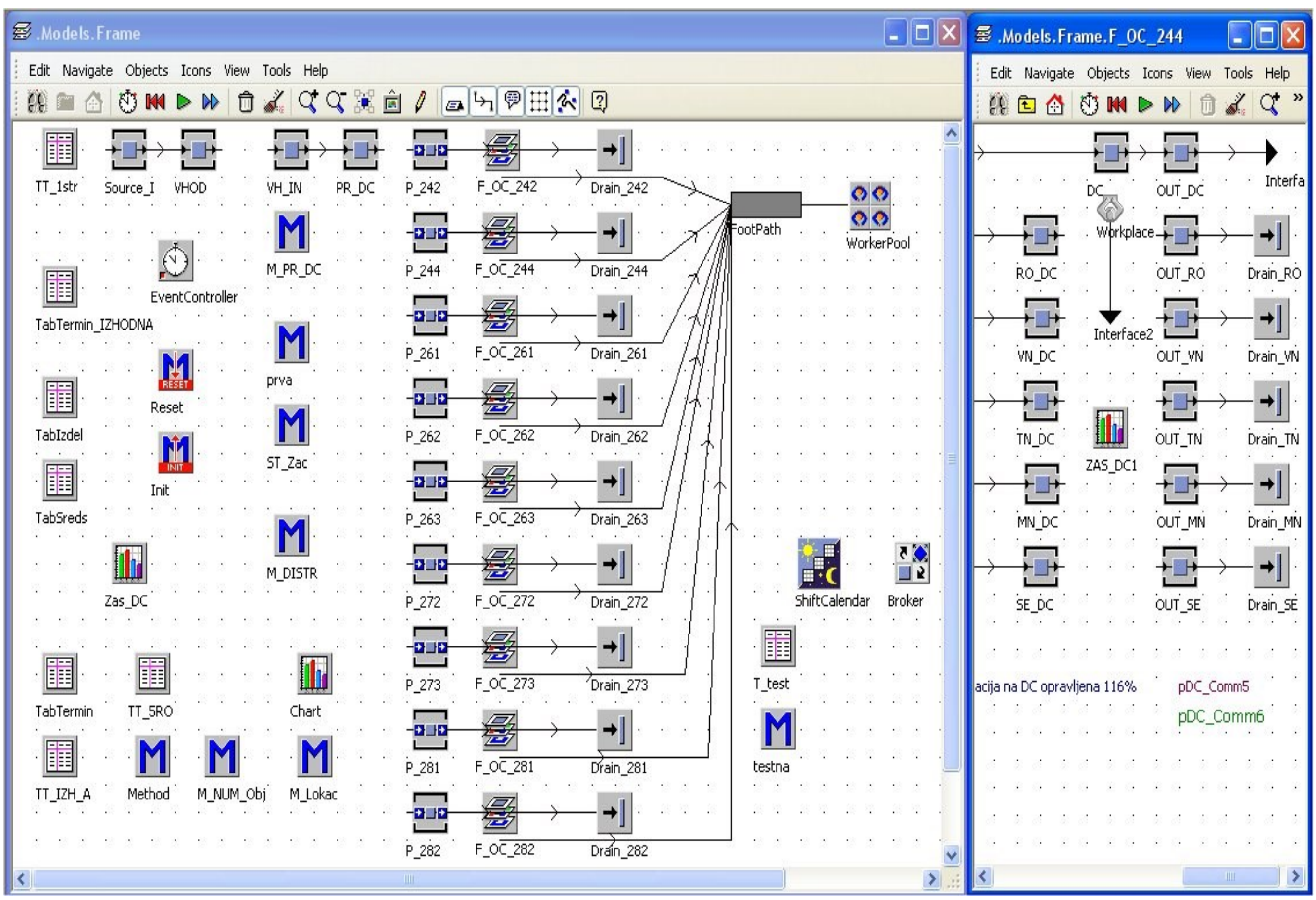

Figure 2. An Example of Virtual Factory for UTP in Plant Simulation [3]

UTP was constructed in a computer environment— Tecnomatix Plant Simulation [9] (see Figure 2). The model was designed as a parametric so that the user in the model inputs data intended for the real production process for the observed period. Among the input data are considered schedule plans, a list of available resources, a work calendar, and the number of available workers. After the initial setup, the user performs a simulation for the desired observation period or for production of the desired number of finished pieces. During the execution of the simulation, the speed can be set for simulation execution, and the simulation can be carried out step-by-step or stopped at any time. It is also possible to configure the production parameters for each production process. In the presented model are pre-designed indicators for real-time tracking of the number of finished parts, consumed production time, and occupancy analysis of individual resources.

The indicators can be displayed in text format on the screen or structured in table format. With simple additions, any indicator can be installed, or any calculations and analysis can be performed on an ongoing basis. A set of input data in the model contains information about the sequence of operations in the production process as well as a list of required resources necessary to perform every individual operation. An output, or acquired data, from the simulation for every individual operation covers the start time of operation execution, the end time of operation execution, and the anticipated duration of operation execution. In the execution of simulation, the user can optionally choose the starting date or observe the output of the production process after a specified number of calendar days.

Model for Large-Scale Production

In the concept for the model of a large-scale production, the assembly or production cell is treated as the elementary unit of the production process; and, in the model, the unit is treated as a sub-model (see Figure 3). The model was developed as parametric in a way that it allows the setting of the production process parameters, which depend on the product type.

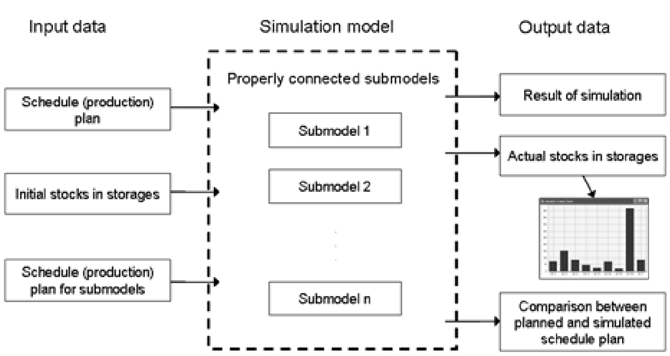

Figure 3. The Logical Scheme of the Simulation Model for Large-Scale Production

In the production process model for LSP, the efficiency of production units plays an important role. This means that the number of produced units depending on production time is significant. Inefficiency of production units occurs as a consequence of scheduled maintenance, parameter setting and calibration, insufficient quantities of materials, and unscheduled stoppages or failures. The next purpose of the model development is the real-time monitoring of stocks in intermediate storage. Stocks should not exceed the maximum capacity that the production process does not stop. Based on the logic model (Figure 3), a simulation model of the production process for LSP was constructed in a computer environment—Tecnomatix Plant Simulation (see Figure 4).

The model was designed as a parametric, where the user inserts the data into the model, which is aimed at the real production process for the observed period. The main schedule plan, the schedule plan for sub-models, the value of the initial stocks in storage, and the work calendar are considered in the input data. A simulation for the desired observation period, or for production of the desired number of pieces, can be performed after the initial setup of the model. The user has an option to set the speed of simulation execution, execute the simulation step-by-step, or stop at any time. The user also has an option to configure the production parameters for each production process in the model.

In this model, the indicators are pre-designed, which enables real-time tracking of the number of finished parts in intermediate storage, consumed production time, and occupancy analysis of individual production places. The indicators can be displayed directly on the screen in text format, in charts, or can be structured in table format. With simple additions, any indicator can be installed in the model, or any calculations and analysis can be performed on-line. Input data are comprised of the sequence of batch production on the production line. In this case, every batch represents a number of identical pieces in the series. An output or acquired data from the simulation for each batch covers the start time of production execution, the completion time of production execution, the expected duration of production execution, and the time spent producing one piece in a batch [9]. As with the UTP model, the user can optionally choose the starting date for performing the simulations or observe the production process for a specified number of calendar days.

In the simulation model, a special chart was designed (see Figure 5) through which an actual state of stock values in intermediate storage can be plotted. This allows the user to continuously monitor the stock movements and compare the values with the maximum capacity of intermediate storage.

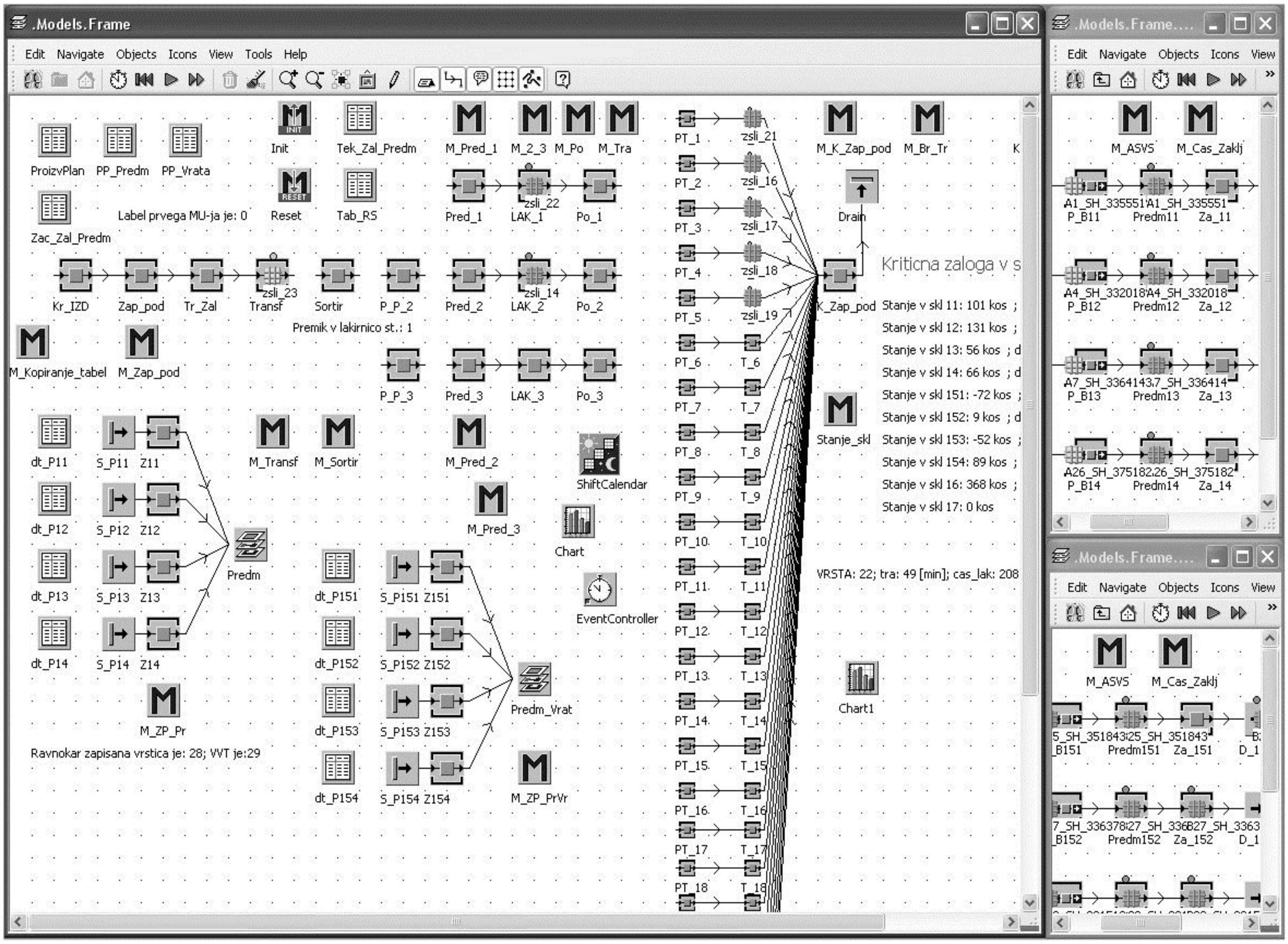

Figure 4. An Example of Virtual Factory for LSP in Plant Simulation

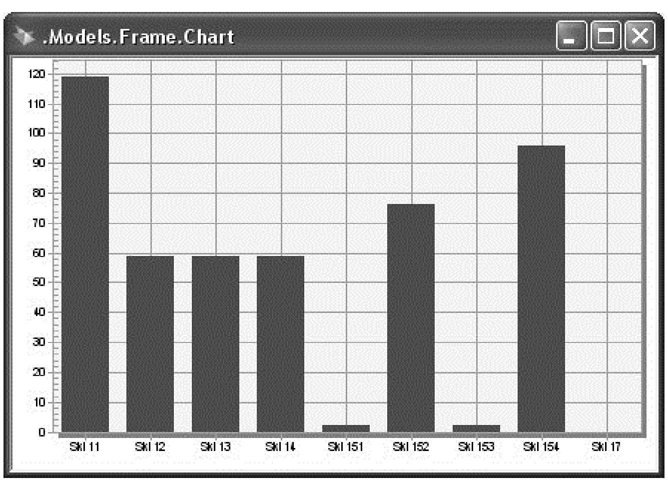

Figure 5. An Example of the Chart for Monitoring the Values of Stocks in Intermediate Storage

Conclusion

Future research will focus on validation of existing approaches through data collection, analysis, and testing. Two models, which were developed as a part of this research study, will be evaluated, analyzed, and tested in the e-environment. The use of both special digital manufacturing models for the purposes of training and education brings a number of advantages. The first advantage is quickly obtaining the simulation results about the estimated execution of the schedule plan. The testing has proven that the execution of a production process in the digital manufacturing models, for an entire work shift, takes only a few minutes. Furthermore, with the testing of production plans in the digital manufacturing models, no intervention in the real production system is necessary and, thereby, does not cause any disturbances. Because of this, the possibilities of testing different schedule plans are practically unlimited, where the behavior of the production system is observed as a function of time for an individual plan or only the outputs of the production system are observed. The models of production processes are designed parametrically, so it is easy to test the input data for different production plans for the purposes of learning. Developed models are user-friendly such that the user inserts the input data into the model, sets the process parameters, performs the simulation, and evaluates the results of the simulation.

Engineers and students can perform a simulation for an existing, or known, production system. They can observe the outputs of the model according to different arrangements in the digital manufacturing models. By using a simulation, they can also study a planned production system, where they test various configurations of the production system or test the response of the planned system to different settings, among which are included the number of shifts, a working calendar, the number of employees, different break times, different process times, the number of machines, variants of parallel processes, transport times, different transport routes, and different manners of transportation strategies for components. Based on the different settings and acquired responses, the engineers and students can determine the optimum production parameters.

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Effectiveness of Problem-Based Learning in Non-Capstone Construction Management Courses

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Abstract

Problem-based learning (PBL) is an instruction approach for enhanced learning and has been adopted in capstone courses in many construction management (CM) programs in the U.S. PBL applied in CM capstone courses has been reported to be effective in student learning. However, no literature on PBL applied in standalone, non-capstone CM courses was found, and the authors were motivated by the potential benefit of PBL in non-capstone CM courses. Therefore, in this study, the authors developed a PBL session for a non-capstone CM course to determine the effectiveness of PBL in student learning. A PBL model was developed by incorporating construction-related videos for a CM course. Effectiveness of the PBL model in the course was evaluated through both PBL sessions and lecture delivery sessions in the course. Student learning was evaluated on two aspects: knowledge gained through pre-test and post-test, and development of critical skills such as critical thinking and teamwork skills through a questionnaire. The result showed that the PBL method was not any more effective than lecturing in terms of a gain in student knowledge, but the PBL model was helpful in the development of critical skills.

Introduction

Problem-based learning (PBL) is an instructional approach that uses problems to initiate, focus, and motivate student acquisition of specific knowledge and development of professional skills and attitudes [1, 2]. Common processes in PBL include: 1) presentation of "ill-structured" problems to groups of students (ill-structured problems are those which require more information for development of a solution than is initially available and which are open-ended and complex enough to require collaboration and thinking beyond recall [3]); 2) student discussion and identification of learning issues that need clarification and research; 3) student exploration for solutions through self-study, discussion, or other resources; 4) student proposals of solutions; and, 5) peer and self-evaluation. In this student-centered approach, benefits of PBL have been proven by many scholars, and the benefits include: 1) student independent learning; 2) responsibility for student learning; 3) interesting and motivating problems; 4) critical thinking stimulation; 5) improvement in communication skills; and, 6) improvement in interpersonal skills (teamwork skill) [3, 4]. Also, Strobel and Barneveld [5] insisted that PBL can contribute to long-term retention of knowledge gained through PBL.

Construction management (CM) includes various aspects such as estimating, planning, contracting, and safety; these aspects of CM are combined and intertwined with each other in the solution of real-life problems in construction [6]. Therefore, the traditional lecture method is not an effective approach to open-ended problems such as real construction problems and is not expected to be able to lead to solutions of real construction problems [7]. Therefore, PBL has been of interest to construction educators, and many CM programs in the U.S. have adopted PBL in their capstone courses [7-11]. CM capstone courses are offered at the senior level and CM students in capstone courses are required to analyze an ill-defined problem and develop their solution in a team by combining and applying what they already learned in other courses [8]. Benefits of PBL in CM capstone courses are reported as development of communication skills and a deeper understanding of the construction industry [12], alongside successful transition to the job market [7].

Except for senior-level capstone courses, other courses in CM programs in the U.S. typically cover each of the various core aspects of CM separately [7]. In these standalone CM courses, the typical delivery format is the lecture method, and attainment of specialized skills and concepts are facilitated [12]. Knowledge gained in the courses is based on precise and well-defined problems selected by the instructor. Thus, the typical CM curriculum with a capstone course and standalone lecture-based courses limit potential benefits of PBL to CM students. Furthermore, current CM students belong to the Net generation. The Net generation student learning style is known to be different from those of existing generations (for example, more efficiency in multi-tasking than previous generations) [13].

Also, Tariq [14] reported that non-traditional learning methods such as active, sensing, visual, and sequential learning are preferred by CM students. The motivation in this study was to examine how CM education may be improved through the PBL method in standalone, non-capstone CM courses in which knowledge acquisition is one of the most important objectives. The hypothesis in this study was that students in standalone, non-capstone CM courses could learn more effectively through the PBL method rather than the typical lecture method, due to the method's inclination to encourage higher motivation and a student-preferred learning style.

Objective and Research Questions

The objective of this study was to evaluate the effectiveness of the PBL method in standalone, non-capstone CM courses. Effectiveness of student learning in this study was determined in two ways: knowledge gained and improvement in critical skills. Therefore, the research questions for this study were:

1. *Do the students learn better under the PBL method than under the typical lecture method in a standalone, non-capstone CM course?*
   This question determines the effectiveness of the PBL method with a focus on student knowledge gained. Obtaining knowledge in standalone, non-capstone CM courses was one of the key objectives, while capstone courses were focused on complicated real-world problem solving. Answering to this question can show if the PBL method is a tool to help students gain knowledge of the subject matter more effectively in CM courses.

2. *Does the PBL help the students develop or improve critical skills (critical thinking, problem solving and communication skills) in standalone, non-capstone CM courses?*
   As reported by several researchers [3-5], benefits of the PBL method include improvement in several critical skills such as independent learning, critical thinking, and communication skills. This question is designed to evaluate the effectiveness of PBL in standalone, non-capstone CM courses with regard to critical skills rather than knowledge gained.

Methodology

A standalone, non-capstone course at the authors' institution was selected for this study. The selected fall 2014 course was an introductory construction course that covered principles, methods, and materials used in the building construction industry. Due to the vast amount of information to be covered, the course was taught by the authors through the lecture delivery method.

Design of PBL in the CM Course

While many benefits of PBL have been reported, one of the disadvantages is that students may not learn about some topics, or gain some knowledge, if a particular problem for the PBL method is not related to those topics [3]. Considering this potential disadvantage of PBL in this study, and the amount of information to be covered in the course, PBL was applied to each topic in one class meeting time (75 minutes) rather than the entire class duration (16 weeks). This approach is quite different from the typical PBL approach used in CM capstone courses. In CM capstone courses, students as a team receive a real-world problem and are required to solve the problem in a single semester.

Use of multimedia as a learning tool has been reported as being beneficial to student learning [15-16]. Therefore, the PBL delivery method in this study included construction-related multimedia (video of a famous TV show) to enhance student learning. The TV show was about fixing problems in houses. In a typical story on the show, the show host is invited to inspect a house with problems such as wrong design, use of inappropriate material, or erroneous workmanship. Then, he identifies the problems, proposes solutions to the problem(s), and fixes the problem(s). Several episodes were carefully selected by one of the authors with regard to the type of problem(s) in the houses. Then, the selected episodes were edited and divided into multiple pieces by following the PBL features: open-ended (or ill-defined) problem. The problem identified by the show host and his solution were not purposefully included in the video shown to the students. After watching the video of an ill-defined problem, students were asked to provide their own solutions. The PBL delivery method in this study was cautiously designed so that the students performed the following jobs:

- Identify the problem(s) at the house.
- Explore what they need to learn about the problem.
- Determine what caused the problem(s).
- Find what solutions are available.
- Determine the best solution.

To perform these tasks, the students were grouped in teams and were allowed to use various resources, such as textbooks and Internet searches. Also, discussion among teammates was highly encouraged. It was expected that the students would become self-learners and perform key functions such analyzing, synthesizing, critical thinking, research, and communication with teammates. Each team was required to turn in written reports, including problem identification and possible solutions. In addition to the students' PBL self-study at the end of each session, the students also watched the part of the video revealing the problems and solutions by the show host. Then the instructor, one of the authors, discussed with the students their problems and solutions in comparison to the show host's problems and solutions.

Lecture versus PBL Delivery

Effectiveness of the PBL method in student knowledge gain was determined by comparing improvements in their knowledge gained through both PBL delivery and lecture delivery methods. The authors prepared four class sessions in which student knowledge gain was evaluated: two sessions using PBL delivery and two sessions using lecture delivery, as shown in Table 1. The topics shown in Table 1 are covered in one class meeting session (75 minutes). Evaluation of student learning on different topics for the two delivery methods (PBL and lecture) was selected, due to a large amount of content (topics) to be covered and limited time allowed for the course.

Table 1. Topics of the Course Sessions for the Study

	PBL delivery	Lecture delivery
Topics	1) Concrete (basic) 2) Low-slope roofing system	3) Heavy timber frame construction 4) Reinforced concrete

For lecture delivery, one of the authors delivered a lecture using a PowerPoint presentation for each of the two topics (heavy timber frame construction and reinforced concrete) without any in-class activity. The other two topics (concrete basic and low-slope roofing system) were covered by PBL delivery. To measure student knowledge gain in both delivery methods, the students in the selected course were required to take quizzes before delivery and after delivery. The quizzes for pre-test and post-test had exactly the same questions in order to determine improvement in student knowledge gain. These procedures are summarized in Figure 1.

The quizzes included multiple-choice questions, and the number of questions on each quiz varied: 6 questions for heavy timber frame construction; 10 questions for concrete basic; 10 questions for reinforced concrete; and, 7 questions for low-slope roofing systems. All of the questions on the quizzes asked for basic knowledge of the subject matter; one example of the quiz is included in Appendix A. The students were asked to make up their own ID and use the ID on all of the quizzes in order to keep track of student knowledge gained and to determine improvement in their learning through both PBL and lecture delivery methods. In addition to student knowledge gain, effectiveness of PBL in standalone, non-capstone CM courses was determined by a questionnaire given to the students participating in the study. The questionnaire included questions which asked students to self-evaluate on improvement in critical skills, which were reported as benefits of PBL by other researchers: motivation, taking responsibility, critical thinking skill, communication skill, teamwork skill, problem-solving skill, and active learning and participation. These questions used a five-point Likert scale: 1) strongly disagree; 2) disagree; 3) neither agree nor disagree; 4) agree; and, 5) strongly agree. Also, student perception about the effectiveness of the PBL method compared to lecturing was asked along with their preferred learning style. The questionnaire is included in Appendix B.

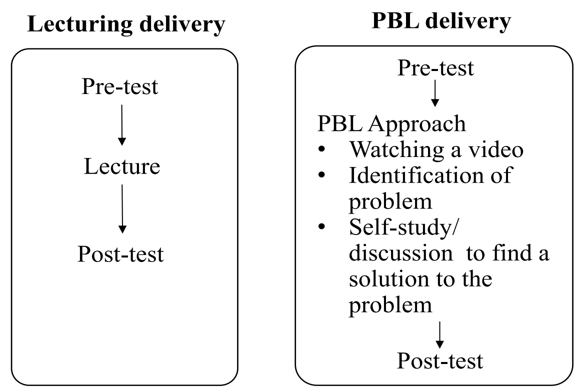

Figure 1. Comparison between Lecture Delivery and PBL Delivery Sessions

Results and Analysis

There were a total of 44 students that enrolled in the course in the fall 2014 semester and recruited for this study. However, the number of responses from participating students on quizzes and the questionnaire varied, due to absences on the day when either PBL or lecture for this study was delivered. Out of the 44 students, 40 responded to the questionnaire; Figure 2 shows the majors of the students. The selected course was required for the CM major in technology education, and CM minor (typically students from the interior design major).

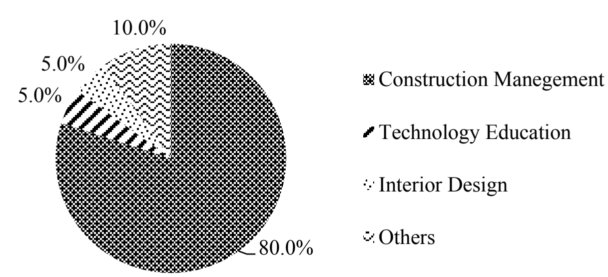

Figure 2. Major of Students that Participated in this Study

Figure 3 shows the students' preferred learning style. Eighty percent of the students preferred learning through hands-on experience rather than lecture or self-study. This result corresponds with the result from Tariq's study [13].

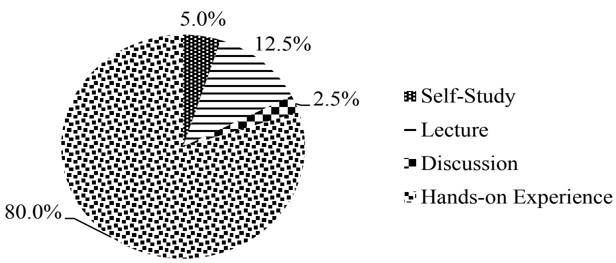

Figure 3. The Students' Preferred Learning Style

Quantitative Assessment of Student Knowledge Gain

The answer to the first question in this study, "Do the students learn better under the PBL method than under the typical lecture method in a standalone, non-capstone CM course?" was evaluated through the change in the students' grades on the pre- and post-tests. Since the number of questions on the quizzes were different, grades on each quiz were converted to a percentage and the difference between the pre- and post-test grades were calculated in order to determine improvement in student knowledge gained. A positive value in grade change meant improvement in a student's knowledge gained, while a negative value indicated a decline in a students' knowledge gained. Table 2 shows a summary of changes in student grades on the quizzes. The mean values of grade change from the two delivery methods were 16.3% and 47.8%, respectively. Through a statistical t-test (on a 95% confidence level), it was concluded that the mean value of grade change through the lecture method was statistically different from that using the PBL method. It indicated that the typical lecture method is more effective than the PBL method for student knowledge gain. Also, the last column in Table 2 shows the number of students whose grades were not improved by either the PBL method or lecture method. A higher number of non-improvements in the PBL delivery corresponds with the conclusion that the PBL method is less effective than the lecture method on student knowledge gain.

Qualitative Assessment on Student Self-Evaluation and Perception

The Answer to the second research question, "Does the PBL help the students develop or improve critical skills (critical thinking, problem solving and communication skills) in standalone, non-capstone, CM courses?" was sought using the questionnaire. Two types of questions were asked on the questionnaire. The first type asked students to self-evaluate whether the PBL method was helpful in development and improvement of critical skills. The second type of question asked students for their perception about which method was more effective in learning.

Table 2. Changes in Grades between Pre- and Post-Tests

	PBL delivery		Lecture delivery	
	Topic 1	Topic 2	Topic 3	Topic 4
No. of responses	39	44	42	38
Subtotal number of responses	83		80	
Mean value of change in grade	16.3%		47.8%	
Standard Deviation	0.22		0.21	
Number of non-improvement	18		8	

Figure 4 shows the students' self-evaluation on helpfulness of the PBL method in the development of critical skills: motivation, taking responsibility, critical-thinking skill, communication skill, teamwork skill, problem-solving skill, and active learning and participation. By adding responses with Strongly Agree and Moderately Agree, the percentages of positive responses for each question were 67.5% (motivation), 77.5% (taking responsibility), 67.5% (critical-thinking skill), 45% (communication skill), 57.5% (teamwork skill), 70.0% (problem-solving skill), and 67.5% (active learning and participation), respectively. Thus, it was concluded that the students thought that the PBL method was helpful in developing all of the critical skills except for communication skills. The next two questions on the questionnaire were about student perception on which method was more effective in general and in the selected course. Figure 5 shows that 70% of the students thought that the PBL method was more effective in general, and 65% of the students selected PBL as the more effective method for the selected course. The last two questions on the questionnaire were about advantages and disadvantages of the PBL method, based on their experience and perception. The students' responses on advantages of the PBL method included

- The students must engage themselves.
- More thinking involved instead of memorization
- More hands on helps grasp concepts.
- It gets the student thinking and more active instead of getting bored and staring into space.
- It lets you find answers yourself and remember better.

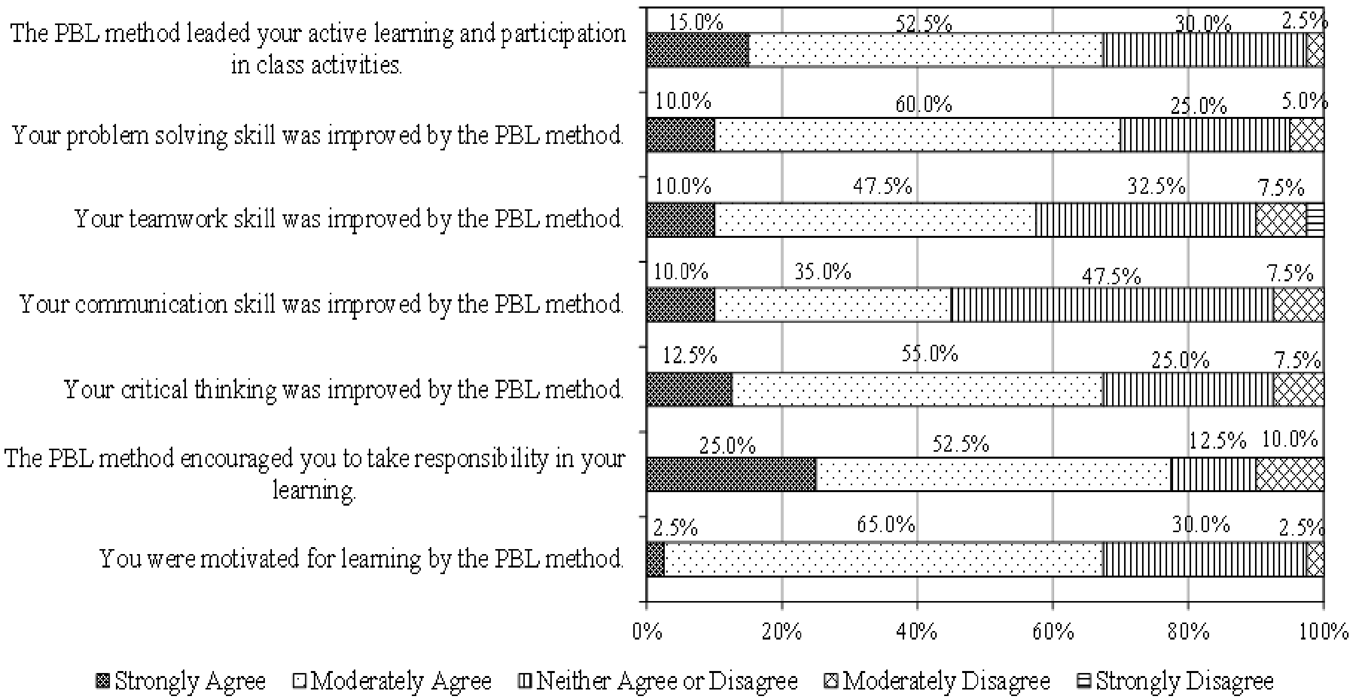

Figure 4. The Students' Responses on Helpfulness of the PBL Method on Critical Skills

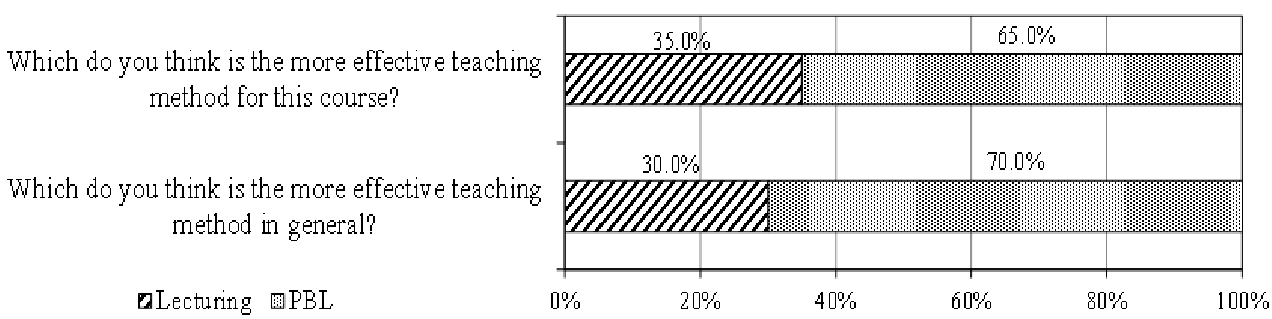

Figure 5. The Students' Perception on the More Effective Method

- Allows students to think critically about problems instead of just having answers put in their mind.
- Teamwork, problem solving
- I had an easier time studying focused during the PBL class.
- You learn more information and retain the information better.

The students' responses on disadvantages of the PBL method included:

- Doesn't touch on all topics/confusing at times.
- Some students don't work well in groups.
- I may not understand fully what I need to about a topic.
- Not a lot of info.
- I believed that I learned more in lecture based learning.
- You might not always learn everything you need to.
- Not always clear whether we have found the correct answers.
- Not finding the right information.
- May not get along in groups and some may prefer lecture.

The students' responses on advantages and disadvantages of the PBL method corresponded with the benefits and disadvantages of PBL found (or reported) in the literature. It should be noticed that the students did not discuss advantages and disadvantages of the PBL method with the instructor in the class. Instead, the authors believe that their responses were from the experience of the PBL method in the selected CM course. These responses indicated that the design and composition of the PBL method in this study was well developed, according to general guidelines for the PBL method.

Conclusion

The PBL method is one of active and effective learning approaches, and many CM programs in the U.S. have adopted the PBL method in capstone courses. The PBL method in CM capstone courses has been reported to be effective in helping students prepare for real-world problems in future careers. The main motivation for this study was potential benefit from application of the PBL method in standalone, non-capstone CM courses. Standalone CM courses are different from capstone courses in that each of the various aspects of CM is covered in a standalone course and knowledge learned in standalone courses is applied in a capstone course.

The objective of this study was to determine the effectiveness of the PBL method on student learning in comparison to the lecture method. A PBL delivery model was developed for an entry-level, standalone CM course. Student learning in four class sessions was evaluated. Student learning was determined based on two aspects: 1) knowledge gained, and 2) improvement in critical skills. Student knowledge gain was evaluated through pre- and post-tests, and improvement in critical skills was measured based on the students' self-evaluation and their perceptions. The results led to the following conclusions:

1) The PBL method is less effective than the lecture method in student knowledge gained.
2) The PBL method is effective and helpful in development and improvement on the students' critical skills: motivation, taking responsibility, critical-thinking skill, teamwork skill, problem-solving skill, and active learning and participation.

While acquisition of knowledge is very important in learning, development of critical skills such as critical thinking and teamwork skill is also critical, especially in construction management industry. Therefore, it cannot be concluded that the PBL method is not recommended for standalone, non-capstone CM courses. Instead, adoption of either the PBL method or lecture method should be determined based on topics covered in each course and features in application of the topics. No current literature provides an answer to the question, "What type of course objective or content in CM courses is the best fit for the PBL method or lecture method?" It requires further research with more detailed research questions regarding different features of CM courses. Furthermore, 70% of the students perceived that the PBL method was more effective than the lecture method in general. This result requires more future research on application of PBL in CM courses.

Future Research

The PBL session for this study was developed according to general guidelines for the PBL approach. The students' responses on advantages and disadvantages of the PBL method corresponded with the advantages and disadvantages reported in previous research. This result indicated that the PBL session was appropriately designed and developed in this study. However, this study included several limitations, as follows.

- <u>Short time period for the PBL session</u>:
  Each PBL session in this study was limited to one class meeting time (75 minutes), and actual time allowed for student self-study and discussion was around 40 minutes at most. However, in typical CM capstone courses, one problem is identified and solved over a half or whole semester. A short amount of time for student problem identification and self-study can limit knowledge acquisition and development of critical skills.
- <u>No evaluation of knowledge retention over a long time period</u>:
  One of the benefits of the PBL method is the retention of knowledge gained over a longer time period and was addressed by the students' responses on the questionnaire. This study did not include evaluation of effectiveness of the PBL method with regard to retention of knowledge.
- <u>Evaluation of student learning on different topics for the two delivery methods (PBL and lecture)</u>:
  Student learning between the two delivery methods was evaluated and compared on different topics, because of limited time and amount of content to be covered. Student learning can be evaluated between two delivery methods on one same topic. The authors plan to compare the effectiveness of the PBL method to that of the lecture method on a single topic in another standalone CM course in the future.

Future research will also overcome these limitations for better application of the PBL method in CM courses. Furthermore, the format of the PBL session may need to be customized to specific topics covered. Non-traditional learning methods have been recommended by several educators and researchers: hands-on approach [17]; practical learning [18]; sensing, visualizing, and active participation [19]; and, visual and hands-on approach [20]. In this study, the PBL approach was combined with multimedia (videos) for motivation. Different formats of non-traditional teaching methods can be incorporated into the PLB approach. Also, a hybrid format between lecture and PBL methods can enhance student learning, depending on content covered and the amount of time for each session.

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Biographies

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Appendix A

POST-TEST: CONCRETE BASICS

This quiz is to evaluate your learning through Problem-based Learning (PBL) and lecture method. This quiz is anonymous and does NOT affect your grade in this course. Please use your own ID (4-6 digits) which was used in the previous test for this study.

ID: ____________________

1. The aggregate for concrete is generally subdivided into coarse aggregate and fine aggregate. The distinction between the two types of aggregates is based on the
   a) Aggregate's strength
   b) Aggregate's surface texture
   c) Aggregate's density
   d) Aggregate's particle size
   e) Aggregate's parent rock

2. The most commonly specified type of Portland cement is
   a) Type C.
   b) Type III
   c) Type PC1
   d) Type I/II
   e) Type II/III

3. Which type of Portland cement is commonly used in making massive structure such as dams?
   a) Type C
   b) Type III
   c) Type PC1
   d) Type IV
   e) Type II/III

4. Portland cement sets and gains strength by virtue of its chemical reaction with:
   a) Water
   b) Oxygen in air
   c) Carbon dioxide in air
   d) Aggregates

5. The test specimen used for determining the compressive strength of concrete in the United States is a
   a) 6-in. diameter, 6-in. –high cylinder
   b) 6-in. diameter, 12-in. – high cylinder
   c) 6-in. diameter, 18-in. –high cylinder
   d) 6-in. diameter, 12-in – high cone

6. A concrete "slump test" is used to determine the:
   a) Weight of a sample batch of concrete
   b) Compressive strength
   c) Type of admixtures used
   d) Consistency of a mix

7. The major advantage of air-entrained concrete is:
   a) Resistance to freeze-thaw cycle damage
   b) Greater tensile strength
   c) Architectural appearance
   d) Resistance to sulfate attack

8. What causes honeycomb in concrete?
   a) Improper consolidation
   b) Usage of too much air-entraining admixture
   c) Big coarse aggregates in concrete
   d) Low water-cement ratio in concrete

9. ( ) is the process of compacting the freshly placed concrete to the forms and around the reinforcing steel to remove air pockets and pockets of stone.
   a) Consolidation
   b) Aggregation

c) Hydration
d) Compression

10. Which concrete admixture is generally used 1) to improve workability, 2) to increase resistance to freeze-thaw cycles and 3) to improve thermal insulation of concrete?
    a) Air-entraining agent
    b) Water-reducing agent
    c) Sand-reducing agent
    d) superplasticizer

Appendix B

SURVEY FOR THE PROBLEM-BASED (PBL) LEARNING METHOD

This questionnaire is to gain information to determine how the PBL activities contributed to your understanding and knowledge. <u>This survey is anonymous and does NOT affect your grade in this course</u>. <u>Please use your own ID (4-6 digits) which was used in the previous test for this study.</u>

ID: ____________________

<u>SECTION I. Basic Information of Participants</u>

1. What is your major?
    a. Construction Management
    b. Technology Education
    c. Interior Design
    d. Others

2. What is your student class?
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior

3. Is this course (TEC 120 Introduction to Building Construction) a required course for your major?
    a. Yes
    b. No

4. Which of the followings describes your preferred learning approach the best?
    a. Self-study
    b. Lecture
    c. Discussion
    d. Hands-on experience (other than discussion)

<u>SECTION II. Participants' Perception on the PBL Method Experienced</u>

5. You were motivated for learning by the PBL method.

Strongly Disagree	Moderately Disagree	Neither Agree or Disagree	Moderately Agree	Strongly Agree
1	2	3	4	5

6. The PBL method encouraged you to take responsibility in your learning.

Strongly Disagree	Moderately Disagree	Neither Agree or Disagree	Moderately Agree	Strongly Agree
1	2	3	4	5

7. Your critical thinking was improved by the PBL method.

Strongly Disagree	Moderately Disagree	Neither Agree or Disagree	Moderately Agree	Strongly Agree
1	2	3	4	5

8. Your communication skill was improved by the PBL method.

Strongly Disagree	Moderately Disagree	Neither Agree or Disagree	Moderately Agree	Strongly Agree
1	2	3	4	5

9. Your teamwork skill was improved by the PBL method.

Strongly Disagree	Moderately Disagree	Neither Agree or Disagree	Moderately Agree	Strongly Agree
1	2	3	4	5

10. Your problem solving skill was improved by the PBL method.

Strongly Disagree	Moderately Disagree	Neither Agree or Disagree	Moderately Agree	Strongly Agree
1	2	3	4	5

11. The PBL method leaded your active learning and participation in class activities.

Strongly Disagree	Moderately Disagree	Neither Agree or Disagree	Moderately Agree	Strongly Agree
1	2	3	4	5

<u>SECTION III. Participants' Perception on Effectiveness of the PBL Method Compared to Lecturing method</u>

12. Which do you think is the more effective teaching method <u>in general</u>?
    a. Lecturing method
    b. PBL method

13. Which do you think is the more effective teaching method <u>for this course (TEC 120)</u>?
    a. Lecturing method
    b. PBL method

14. What do you think <u>advantages</u> of PBL method compared to lecturing method are, if any?
    (   )

15. What do you think <u>disadvantages</u> of PBL method compared to lecturing method are, if any?
    (   )

USING MULTISIM/ELECTRONIC WORKBENCH IN BASIC ELECTRICITY COURSES IN LIEU OF OR TO COMPLEMENT LIVE LAB EXPERIMENTS

Jimmy Bill Linn, East Carolina University

Abstract

One of the main obstacles to bringing technology and engineering classes online is the necessity of a laboratory component to the course to reinforce theoretical concepts discussed in the lecture part of the course. In the past, this has necessitated actual laboratory experiments using physical equipment and parts. Recently, however, virtual tools have become available to simulate laboratory experiments so that physical equipment and parts may not be necessary. In this paper, the author evaluates such an approach in a basic electricity course using electronic circuit simulation program from National Instruments called MultiSim. The course was offered using traditional hands-on laboratory experiments and assessment scores were recorded. The course was then offered using the virtual lab simulation software and assessment scores were again recorded. The results suggest that such virtual methods may be a viable substitute or complement to actual laboratory experiments in electricity courses.

Introduction

The most significant impediment to bringing technology and engineering courses online is the necessity of reinforcing important theoretical concepts taught in the classroom with live hands-on laboratory experiments to reinforce and drive home important points about these theories. Because live experiments involve expensive equipment and materials and parts, which are generally not available at online learning sites like business training centers or student homes, it becomes impractical to offer technology and engineering courses online. In this paper, the author introduces a solution to this problem for basic and intermediate electricity courses.

The idea is that the use of MultiSim/ Electronic Workbench electronic circuit simulation software can replace most if not all in-class circuit experiments. This allows the instructor to use circuit schematic diagrams of virtually any circuit to reinforce the appropriate theoretical concepts discussed in the lecture part of the course. In addition to reinforcing theoretical concepts, the use of schematic diagrams trains students to read and understand electrical schematic diagrams that are critical to understanding electrical equipment and how that equipment is wired. Complementary software (Ultiboard) not discussed in this paper further teaches students how schematic diagrams are converted to printed circuit boards with inserted electrical parts.

Instructors have two options when incorporating MultiSim into their electrical courses. In option one, the instructor may construct laboratory assignments using schematic diagrams in MultiSim for the students to analyze. This allows the software to work well for instructors that wish to have total control over the student's learning experience, even in more advanced electrical courses. But the instructor may also introduce real equipment into the course so that the experience is not totally left out. In option two, the instructor may choose from a number of in-print laboratory manuals that have pre-written laboratory experiments with already prepared MultiSim circuits. This works well for instructors new to MultiSim.

Before adopting simulation software, be it MultiSim or another brand, it is important to do a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis. The strengths of this approach are the elimination of costly lab equipment and lab space for students, no burned up parts from incorrectly wired experiments that delay the completion of the lab and often confuse the students and weaken the student's reinforcement of the important electrical theory and concepts the lab is intended to reinforce. Instructors may also assign lab assignments as homework, where they have much more time to experiment and make changes to the circuit to see how these changes affect circuit performance. Completed experiments along with discussion may be handed in at the beginning of the next class. Weaknesses include the lack of hands-on experience traditional instructors claim is vital to student learning experience. Another potential weakness is that, when instructors choose to have only homework assigned labs, the social experience where students solve problems and pass this experience to other students is missing. And finally, in addition to learning about electricity, students must now learn how to load, install, and use the software. This may distract the student from focusing on the intended reinforcement of theoretical concepts. Opportunities include expanding previously unavailable technical and engineering classes to online classes, thus drastically improving course availability to students. Threats include a weakening of the equipment base that strengthened the student cultural environment of the university experience.

Literature Review

Other work in this area has been done so that a fairly solid comparison may be made with the work discussed in this paper. One such case study involved the use of simulated laboratory experiments in a high school physics class [1]. The major problem of this study was to assess the effect of computer-simulated experiments on the attainment of process skills and the acquisition of subject matter content in the high school physics laboratory. Over a 4-month period, 51 students from two physics classes were involved in four laboratory experiments and simulations. There was a random assignment of students to one of three treatment groups: laboratory, laboratory-computer, and computer. The process skills investigated were the ability to investigate relationships between laboratory variables (Data Manipulation score), to reach conclusions (Experimental Conclusion score), and to interpolate, design experiments, and reach conclusions (Process Tests). The data obtained were subjected to analysis of variance and covariance. Among the results, it was found that the computer-related group had the highest mean Data Manipulation score, while the laboratory -computer and laboratory groups had higher mean Process Test scores, although the differences were not significant.

Another case study at Northwestern University involved the use of computer-simulated laboratory experiments in engineering technology [2]. This study examined the effectiveness of using computer simulation software for laboratory instruction in lieu of using actual components and equipment in a hands-on hardware laboratory. Furthermore, the research analyzed student attitudes toward the two laboratory environments. The results showed that there were no significant differences in student achievement between a simulated laboratory exercise and the same laboratory exercise offered as a traditional hardware laboratory. The attitudinal study revealed some differences between the two approaches, especially in the students' perceived ability to troubleshoot electronics circuits. One hallmark of an engineering technology program is the hands-on laboratory experience. In fact, the criteria for accrediting engineering technology programs specify that theory courses "should be accompanied by coordinated laboratory experiences." A laboratory course accompanies almost every electronics engineering technology course at Northwestern State University. In these laboratories, students construct (or, in more advanced courses, design and construct) electronic circuits and machines. Students then use electrical test equipment to measure the characteristics of circuits and machines and compare their findings with theory presented in the corresponding lecture courses. A typical hands-on laboratory station provides the student with a suite of expensive test and measurement equipment.

Despite the extensive use of hardware laboratories in the curriculum, the administration and faculty at Northwestern want to increase course offerings to employees of regional industries and to other nontraditional learners, who are not free to attend class during normal classroom times. While lecture instruction can be delivered at a distance using online and other technologies, it is difficult, if not impossible, to reproduce the hands-on experience of an electronics laboratory over the Internet. Nevertheless, an electronic engineering technology program delivered online must include concurrent laboratory experiences.

In recent years, a number of commercial computer-aided simulation programs such as Computer Simulated Experiments for Electric Circuits Using Electronics Workbench MultiSim by Richard H. Berube have become available. "Researchers have compared the effectiveness of some of these programs to the effectiveness of traditional hands-on laboratory exercises" [1-3]. Most of these research efforts investigated the use of computer-aided software as a method to enhance, enrich, or improve traditional lecture or laboratory courses. One researcher noted that studies of the influence of media on learning have been a fixed feature of educational research since Thorndike (1912) recommended pictures as a labor-saving device in instruction. Most of this research is buttressed by the hope that learning will be enhanced with the proper mix of medium, student, subject matter content, and learning task [2]. The objective of the study was to compare the achievement of a group of electronic engineering technology students that used computer-aided simulation software to complete a set of laboratory experiments (the treatment group) with a group of students that used a traditional hands-on laboratory for the same set of experiments (the control group). This objective was formulated to investigate the feasibility of offering electronics laboratory courses in environments where traditional hardware laboratories are unavailable.

The quantitative research showed no significant differences in conducting electronics laboratory experiments by computer simulation and conducting the same experiments in the hardware laboratory. Averages compiled at the end of the semester provided the most compelling evidence for the findings. Paired-sample t-tests showed no statistically significant differences between the control and experimental groups for either the freshmen or the juniors. The combined results from the freshman-level and the junior-level courses also showed no significant difference [2].

For the freshmen, the paired-sample t-test results showed no statistically significant differences in the mean post-test scores between the groups. A multivariate analysis showed that the observed power was small. Despite the large probability of accepting a false null hypothesis (type II error), the small effect size would indicate that there would be no practical significance even if statistical significance were forced by enlarging the sample [2]. In addition, the results of the Likert-scale questionnaires were revealing. The freshmen showed no statistically significant differences in their responses to any of the four questions. This result indicates that they did not have a preference for either environment in terms of learning the objective of the laboratory, learning the theory, or learning troubleshooting [2].

Similarly, the results of the t-tests of mean post-test scores from the juniors were not statistically significant. A multivariate analysis showed that the observed power was moderate for the sample size and that the effect size was small and of little practical significance. In contrast to the freshmen, the juniors showed statistical significance in their answers to all four Likert-scale questions. The juniors' responses indicated a preference for the hardware laboratory in learning the objective, learning the theory, and learning troubleshooting. The juniors' "statistically significant attitudes" did not match their mean post-test scores. There was no significant difference between the experimental and control mean post-test scores. Inasmuch as the juniors' mean post-test scores were higher in favor of the hardware lab after six of the eight lab exercises, their attitudes were reflected in their performance, but not to the same degree [2].

A third case study looked at using simulated laboratory experiments in middle school science classes from grades 6 through 9 [4]. At this very volatile age, teachers need to stimulate the inquisitiveness of students to maintain interest in science. Until recently, computer simulation software has not been good enough for this application. But of late, that is changing. Computer technology is poised to make a significant difference in the way middle school students learn science. Exploration in middle school science represents just one of a new generation of science instructional materials that moves beyond tutorial instruction by using the computer to involve students directly in scientific thinking. A combination of computer-simulated laboratory experiments and networked audio and video will better enhance the students learning experience and stimulate their inquisitiveness. It is vitally important that this type of resource be introduced to students at an early age. Two significant advantages are gained; first that these students benefit from this resource at a time when their young minds are developing and benefits are maximized, and second that by the time students get to the college level, they are comfortable using these simulation tools and can again reap maximum benefit from them.

Dr. Brian Woodfield at Brigham Young University (BYU) pioneered the use of simulation in a chemistry lab with a product called "Virtual Chem lab" [5]. This software allows students to perform many typical chemistry experiments such as titration, calorimetry titration, Milikan oil drop, spectrometer, FTIR, and many others. In a real chemistry lab, experiments are tedious and time consuming to set up. Since we are dealing with potentially unsafe materials, concern for safety is always present. The Virtual Chem Lab (VCL) vastly shortens that setup time, which tends to stifle experimentation and creativity among students. Over the years, BYU has found VCL to be as useful as any other tool in the classroom. In other words, most of its effectiveness depends on the teacher or professor using it. Implementation is key, and instructors with a positive attitude will have the most success with the product.

Researchers found that students take from 15 to 30 minutes to learn the interface, and that giving students the Herman Brian Dominance Instrument before classes using VCL helps pinpoint those who prefer direct instruction over personal discovery and who may need more initial assistance with the program. VCL seems to be most useful when assigned as homework. Instructors have noted up to a 30% increase in performance on exams in classes using VCL versus those who do not. Also, students not using VCL invariably performed poorly on quizzes over the covered material. In addition to VCL, BYU also finished a virtual physics lab, physical sciences lab, and a general and organic chemistry lab.

Another researcher, in his article entitled, *Generalizing Test-Enhanced Learning from the Laboratory to the Classroom* [6] discussed and compared simulated lab experiments and hands-on lab experiments in which the purpose of simulated lab experiments as well as hands-on experiments was to reinforce topics covered in lecture. The best and most proven method of assessment for learning technical concepts and theory, according to this article, is short-answer or multiple-choice testing. This article also established the baseline for assessing whether simulated lab experiments or hands-on lab experiments are the best method for technical theory reinforcement.

Using MultiSim in AC/DC Electricity Courses

A number of authors have created lab manuals with virtual labs that instructors may use. For the Circuits 1 course evaluated in this paper, *Computer Simulated Experiments* *for Electric Circuits Using Electronics Workbench MultiSim* by Richard H. Berube [7], that may be assigned either as an in-class lab or a homework assignment, was used. These assignments are divided up into three main sections. The first section gives applicable theory and background. The second section is a step-by-step set of instructions and questions to focus the student on the pertinent theoretical concepts the lab is to reinforce. The third section is a troubleshooting section that stretches the student's understanding of the concepts and focuses on practical application.

The effectiveness of using MultiSim as a laboratory tool was measured by collecting exam and lab assignment grade data from a Circuits 1 course, where MultiSim was not used as a control, and collecting the same data from the same course, where MultiSim was used in lieu of live lab experiments.

Performing a hypothesis test, the null hypothesis was:

H_0 = Changing lab methods has no effect on grade point average.

The alternate hypothesis was:

H_A = Changing lab methods does affect GPA.

Ten students were sampled from each lab method group. The ten students from each group were traditional students from Ivy Tech Community College. Using the paired t-test, the t statistic was 0.0181. As a result, the null hypothesis was rejected and it was concluded that changing the lab method does affect GPA. Now, looking at the mean for each lab method, (mean = 2.70 for the class using traditional lab methods and 3.70 for the class using MultiSim virtual labs) the mean was higher by one full point (grade) when the MultiSim labs were used. From this examination then, it can be concluded that the MultiSim labs improve GPA performance.

Results and Conclusions

This researcher does not suggest that all electronics labs be converted to computer-based labs, simply that a range of 33%-67% of computer-based lab experiments is a good starting point. The learning environment, types of students, and other factors will serve to fine tune this percentage. It is very important to remember that the use of new and innovative methods in the classroom is only another tool to be used to facilitate the learning process. The flow diagram in Figure 1 should be considered when deciding if this tool is applicable to a given situation. First, course objectives must be evaluated to determine if a computer-based lab model is consistent with reinforcing those objectives. If the answer is yes, then a search for applicable off-the-shelf software must be done to determine if available software will meet training and education requirements. If no such software is available, consider a custom software arrangement. Is it cost effective? Figure 1 shows that the decision process for deciding if computer-based laboratory experiments is the correct choice is not trivial. Each of these decisions must be carefully evaluated.

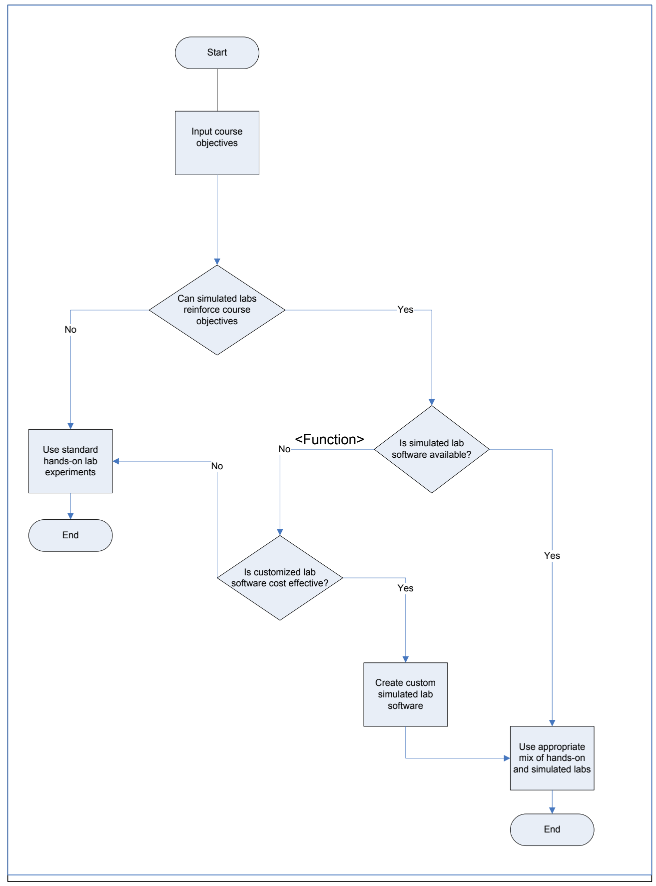

Figure 1. Simulation Software Decision Flowchart

The use of simulation software in the classroom is not restricted only to electrical courses; it may also be used in a wide variety of technical and engineering courses. Additional research is recommended to determine the effectiveness of the proposed simulation software in other technology and engineering areas besides electricity and electronics courses. One should also consider appropriate intangible factors as well such as student feedback and accuracy of the simulations. In some classes, like robotics, student feedback regarding robot simulation software has been overwhelmingly positive. If the robot simulation software is a very close and accurate simulation of the robot that students are being trained on, students get a very good feel for the actual robot, and the programming and training goes smoothly. Often, working with robot simulation software may prevent damage either to the robot or surrounding equipment, due to inexperienced programming. This and other applications of laboratory simulators, such as the use of a laboratory simulator in electric power systems [8], shows the broad range of application for this technology.

All of the examples of the use of computer-based technology in the classroom discussed in this paper were based on the application in a traditional face-to-face classroom with face-to-face laboratory classes. But possibly the most far-reaching positive results may well be obtained in distance education. With distance education, face-to-face contact is minimized. Computer-based tools are the prime implementers of this form of education, and the use of computer-based laboratory tools and the application of this technology in the laboratory is a significant contributor to the success of distance education, where it is successful in technology, engineering, and engineering technology education. Distance education is the key to allowing more people to get or advance their education and make lifelong learning possible for everybody. The use of computer-based tools for lecture and both computer-based and multimedia tools in laboratory environments holds the key to a successful distance education course.

In this discussion, examples of the use of innovative technology in the classroom have been put forth. The use of simulation software has been evaluated in an electricity class. Various methods of assessment have been used to assess the impact of using these methods. Exam scores and student feedback are two very important assessment tools used. In the environments discussed here, these assessment tools were very positive. It is this researcher's sincere hope that readers may use these and other innovative technologies in their classrooms to advance distance learning and reach more students in order to provide them with a quality education.

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Biography

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