© 2015 IJSRSET | Volume 1 | Issue 5 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Competence-Based Training in Higher Education Institutions

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ABSTRACT

Keeping students engaged and motivated in higher institutions of learning is challenging, even for the most experienced professors. Although it is difficult to prescribe a "one-size-fits-all" approach, research shows that there are practices that will generally encourage students to be more engaged. These practices include moving away from rote learning and memorisation to providing more challenging, complex work; having different approached and encouraging cooperative learning. Competency-based training has been shown to provide a number of advantages in ensuring that the trainees are equipped with knowledge and skill in specific areas at workplace. In this paper, we advance and discuss descriptively a new approach for teaching microprocessor course unit using simulation software freely available on the Internet using project-based training that is well rooted in competency-based training. This approach allows students the opportunity to learn to use the microprocessor as a tool for solving engineering problems and not just for them to understand the architecture of the microprocessor. The approach consists of shifting the focus of the course from the microprocessor itself to learning the application the microprocessor is used for as a tool to solve practical engineering problems. Ideas to facilitate implementation of the approach are raised and we finally discuss some of the benefits to engineering education.

Keywords: Competency-Based Training; Project-Based Teaching; Competency Identification; Project Goals; Microprocessor

I. INTRODUCTION

Competency-based training approach originated from parallel developments in vocational training in many countries such as the national qualifications framework in New Zealand, the national training board in Australia, the national skills standards initiative in the United States and the national vocational qualifications (NVQs) in the United Kingdom.

The reason for this evolution in training may have been the need to make the national workforce more competitive in the global economy. The approaches outlined a set of standards each broken down into elements by which performance in the workplace could be assessed.

Competency-based training identifies basic essential elements which consist of functional analysis of the occupational roles, translation of these roles (competencies) into outcomes, and assessment of trainees' progress in these outcomes on the basis of demonstrated performance.

Progress is defined solely by the competencies achieved and not the underlying process or time served in formal educational settings. Assessments are based on a set of clearly defined outcomes so that all parties concerned (lecturers and students) can make reasonably objective judgements about whether or not each student has achieved them. Potential benefits of the approach include individualised flexible training and transparent standards, because almost all learners can learn equally well if they receive the kind of instructions they need.

In traditional educational system, the unit of progression is time and is teacher-centred. In competency-based training system, the unit of progression is mastery of specific knowledge and skills and is learner-centred. In competency-based training, we define; (i) skill as a task or group of tasks performed to a specific level of competency or proficiency; (ii) competency as skills performed to a specific standard under specific conditions.

Creemers et al [1] concludes that competency-based training has tremendous potential for training for industry. A competent technologist is one who is able to perform a technological skill to a satisfactory standard.

In engineering and technology training, competency-based training is based upon the learner's ability to demonstrate attainment or mastery of engineering and/or technology skills performed under certain conditions to specific standards (the skills then becomes competencies).

Thomas and Patel [2] identify five essential elements of competency-based training system:

i. Competencies to be achieved are carefully identified, verified and made known well in advance.
ii. Criteria to be used in assessing achievement and the conditions under which achievement will be assessed are explicitly stated and made known in advance.
iii. The teaching methods and schemes provide for the individual development and evaluation of each of the competencies specified.
iv. Assessment of competency takes the participants knowledge and attitudes into account but requires actual performance of the competency as the primary source of evidence.
v. Learners progress through the instructional program at their own rate by demonstrating the attainment of the specified competencies.

II. CHARACTERISTICS OF COMPETENCY-BASED LEARNING

Competency-based learning has the following characteristics [2]:

- Competencies are carefully selected,
- Essential knowledge is learnt to support the performance of skills,
- Detailed training materials are keyed to the competencies to be achieved and are designed to support the acquisition of knowledge and skills,
- Methods of instruction involve mastery learning, the premise that all participants can master the required knowledge or skill, provided sufficient time and appropriate training methods are used,
- Learners' knowledge and skills are assessed as they enter the program and those with satisfactory knowledge and skills may bypass training or competencies already attained,
- Learning should be self-paced,
- Flexible training approaches including large group methods, small group activities and individual study are essential components,
- A variety of support materials including print, audiovisual and simulations (models) keyed to the skills being mastered are used,
- Satisfactory completion of training is based on achievement of all specified competencies.

III. ADVANTAGES OF COMPETENCY-BASED LEARNING

Although competency-based approach appears especially useful in training situations where trainees have to attain a small number of specific and job-related competencies [3](Watson et al., 2002), the following advantages are realised in general:

- Learners achieve competencies required in the performance of their tasks,
- Learners build confidence as they succeed in mastering specific competencies,
- Learners receive a transcript or list of the competencies they have achieved,
- Training time is used more efficiently and effectively as the trainer is a facilitator of learning as opposed to a provider of information,
- More training time is devoted to working with participants individually or in small groups as opposed to presenting lectures,
- More training time is devoted to evaluating each participant's ability to perform essential job skills.

IV. COMPETENCY-BASED TRAINING IN PROJECT-BASED TEACHING

Research shows that there are practices that will generally encourage students to be more engaged. These practices include moving away from rote learning and memorisation to providing more challenging and complex work.

Project-based instruction is a holistic instructional strategy rather than an add-on. Lecturers increasingly can teach groups of student who may have different learning styles and ability levels.

Project-based instruction builds on the student's individual strengths and allows them to explore their interests in the framework of defined tasks within the curriculum. The students plan, implement and evaluate their projects that have real-world applications beyond the classroom. This approach is rooted in competency-based training in which students learn by constructing new ideas or concepts based on their current and previous knowledge[4] (Karlin and Vianni, 2001).

Most important under this approach is that students find projects, motivating and challenging because they play an active role in choosing them, choosing the method of implementation and in the entire planning process [5](Barab et al., 2005).

V. OUTLINING PROJECT GOALS

It is important for clarity in the goals of the project so that it is planned and completed effectively within the stipulated time. The lecturer and the students should develop an outline that explains the project's essential elements and expectations for each project. The outline may take the following elements:

i. *Situation of problem*: a sentence or two describing the problem that the project is trying to address.
ii. *Project description and purpose*: a concise explanation of the project's ultimate purpose and how it addresses the situation or problem. E.g. students will research and do literature review about the topic in the project and devise ways to get solution.
iii. *Performance specifications*: a list of criteria or quality standards the project work must meet.
iv. *Rules*: Guidelines for carrying out the project including the timeline and short-term goals, such as milestones.
v. *List of project participants with roles assigned*: Include project teammates and their roles
vi. *Assessment*: How the students' performance will be evaluated. In project-based learning, the learning process is being evaluated as well as the final product.

VI. CURRICULUM DESIGN

At present, the curriculum for Bachelor of Science in Electrical and Electronic Engineering at the Technical University of Mombasa at the fourth year of study includes the following engineering course units: Control Engineering I; Power Electronics II; Analogue Filters; Microprocessor I; Power Systems I; Electrical Machines IV; Signals & Communication II; Visual Display Systems I; Instrumentation; Control Engineering II; Microprocessor II; Power Systems II; Electrical Machines V; Illumination Engineering; Microwaves; Visual Display Systems II; and Integrated Circuits. Laboratories dedicated to this curriculum as required by the Kenya's Commission for University Education (CUE) and Engineers Board of Kenya (EBK) are being developed through identification of key competencies the students are expected to learn. Each laboratory exercises consist of a set of tasks for the student to undertake and all students undertake the same set of tasks in a given practical course unit.

In this paper we highlight the typical competencies for ***Microprocessor I*** course unit developed on the basis of the Intel 8085 Microprocessor. The exercises were broken down into competencies and skills on the topics as are described in the course unit as explained in the following section.

VII. METHODOLOGY : PROJECT-BASED TEACHING OF MICROPROCESSOR I

The broad definition of project-based learning given by [6] has been adopted: Project-based learning begins with an assignment to carry out one or more tasks that lead to the production of a final product—a design, a model, a device or a computer simulation. The culmination of the project is normally a typed and/or oral report summarizing the procedure used to produce the product and presenting the outcome.

Project-Based teaching of microprocessor presents the microprocessor as a viable tool for solving a wide range of industrial-type monitoring and control design problems in a way that is appealing and applicable to all engineering disciplines. The mechanism or vehicle which was proposed to accomplish this goal is to build the course around a real-world and application problem. Designing the application would require knowledge of important functions of the microprocessor.

The idea is to follow a step-by-step approach for solving the problem using the microprocessor and to cover the inner workings of the microprocessor only as needed to solve the problem. In this way, the focus originates at the application itself and goes all the way to the details of the microprocessor which are required to be able to use the microprocessor to solve the problem.

Applications could be selected to match the students' background; in this way microprocessor classes become more universal and less restricted to electrical engineering students.

In this approach, the following competencies were identified that made teaching of microprocessor course interesting to students:

Competency 1: The students should demonstrate an understanding of the history of microprocessors and major recent computer developments by:

i. Outlining the history of computers.
ii. Explaining the role of computers in business, scientific usage, control systems, and the military.
iii. Defining and explaining microprocessors, floppy disc memories, large scale integration and microprogramming.
iv. Recognizing terminology used in technical literature and in industry.

Competency 2: The students should demonstrate an understanding of the fundamental hardware circuitry and architecture of modern digital computers by:

i. Defining list of components and peripherals of a typical personal computer.
ii. Explaining the function of each component: microprocessor, memory, and input/output (I/O) devices and their line of communication (buses).
iii. Using assembly language and high level language and explaining the advantages of an assembly language over high level languages.

Competency 3: The students should demonstrate an understanding of the data flow inside the microprocessor by:

i. Explaining the fetch and execute cycles.
ii. Defining the microprocessor signals and their classifications
iii. Explaining chip design terminology and functionality, including Small Scale Integration (SSI), Medium Scale Integration (MSI), large Scale Integration (LSI), bit, byte.
iv. Explaining the terms ASCII, word, instruction, software, and hardware.
v. Explaining the logic instructions, and recognizing the flags that are set or reset for given data conditions.

Competency 4: The students should demonstrate an understanding of the microprocessor architecture, microcomputer systems, and memory interfacing by:

i. Defining the address bus, the data bus, and the control bus and explaining their functions in reference to the 8085 microprocessor.
ii. Explaining the functions Reset, Interrupt, Wait, and Hold.
iii. Explaining memory organization and memory map, and explaining how memory addresses are assigned to a memory chip.
iv. Recognizing the functions of various pins of the 8085 microprocessor.
v. Listing the various internal units that make up the 8085 architecture, and explaining their functions in decoding and executing an instruction.
vi. Drawing the block diagram of an 8085-based microcomputer

Competency 5: The students should demonstrate an understanding of the basic software techniques, including both machine and assembly languages by:

i. Explaining the functions of data transfer (copy) instructions and how the contents of the source register and the destination register are affected.
ii. Explaining the functions of the machine control instructions HLT and NOP.
iii. Writing a program in 8085 mnemonics to illustrate an application of data transfer instructions, and translating those mnemonics manually in their Hex codes

Competency 6: The students should demonstrate a basic understanding of the fundamental principles of digital computers and computer circuitry by:

i. Identifying the basic components of digital computers, including, Input devices, Control element, Storage, Arithmetic element, Output devices.
ii. Explaining the central processing units (CPU) operation and processes.
iii. Demonstrating the use of software to examine the operation of the CPU.
iv. Describe the BUS concepts and use.
v. Identifying and applying addressing modes in assembly language programming.
vi. Writing, assembling, executing, and debugging assembly language instructions
vii. Identifying the various types of RAM and ROM memories and explaining how they interface to the microprocessor.
viii. Interfacing input and output devices with the microprocessor

Competency 7: The students should demonstrate the ability to output data using different instructions by:

i. Defining and using the instruction word.
ii. Charting the flow of a basic assembly language program.
iii. Hand assembling programs written in assembly language and relating the hand assembling to assembler action.
iv. Exercising the use of transfer of control instructions in development of subroutines programs.

Competency 8: The students should demonstrate how to apply the basic rules of arithmetic for positional significance number systems to those systems normally used in the computer field by:

i. Defining the characteristics of a positional significance number system with any radix.
ii. Converting between binary, octal, decimal, and hexadecimal number systems.
iii. Performing simple arithmetic operations in the binary and hexadecimal number systems.
iv. Identifying the characteristics of common computer information codes.

Competency 9: The students should demonstrate understanding of the functions and inter-relationships of the elements that comprise a microprocessor based computer by:

i. Drawing the block diagram and describing the basic architecture of a microcomputer.
ii. Identifying and giving functional descriptions of data, address, and control buses.
iii. Describing the internal architecture of the 8085 microprocessor.
iv. Explaining the function and operation of each register in the 8085 microprocessor.
v. Describing the sequence of operations in the execution of a microprocessor instruction

Competency 10: The students should demonstrate how to use assembly language mnemonics to write programs and how to code assembly language instructions in binary by:

i. Writing data-handling and arithmetic instructions.
ii. Writing logic instructions.
iii. Creating condition code testing and branching instructions
iv. Programming registers and stacks operations.
v. Programming communication between the computer and I/O devices.

VIII. USE OF SOFTWARE TO TEACH MICROPROCESSOR

The use of simulation software to teach microprocessor is an attempt to apply visual programming techniques to programming assembly language applications. We believe that this approach could lead to assembly language tools for helping students learn how to master this tedious and exacting activity, and for improving the productivity and accuracy of professional programmers.

The proposed approach may be suited for every course especially in electrical engineering curricula. Electrical engineers who are interested in designing controllers for a variety of applications will find this approach very beneficial as long as tasks are well identified for the design of the controllers for the recognized applications.

Our major recommendation for teaching Microprocessor course is through defined projects where the students are given in the beginning of the semester and they are guided in pursuing them to the end of the semester. This has been tested and found that the method provides students with opportunities to learn microprocessor at greater length, with appropriate details. This also ensures that students gain a variety of ways of tackling programming problems in quest to solving engineering problems.

In the project-based teaching the students work jointly in groups meaning that students must learn to work together to take common decisions and figures out how to share and coordinate work among them [7]. The students learn through these study processes how to plan, manage and evaluate projects. Through this the students develop study competencies, which also must involve the ability to handle large amounts of information, which is within easy reach via the library, databases and the Internet.

This method of pedagogy makes it possible for students to turn into autonomous, but collaborative and critically thinking students. Education should not only focus on learning a specific course and reproduce what is taught by the lecturer. The real challenge is to open up for a personal meaningful process where new ways of thinking are made possible. Thus students may learn to embark into lecturer-defined projects and get involved in quite demanding but enriching practices.

While teaching can be confined to the lecturer's efforts towards effective learning, in competence-based learning on the other hand can occur without much effort on the part of the lecturer.

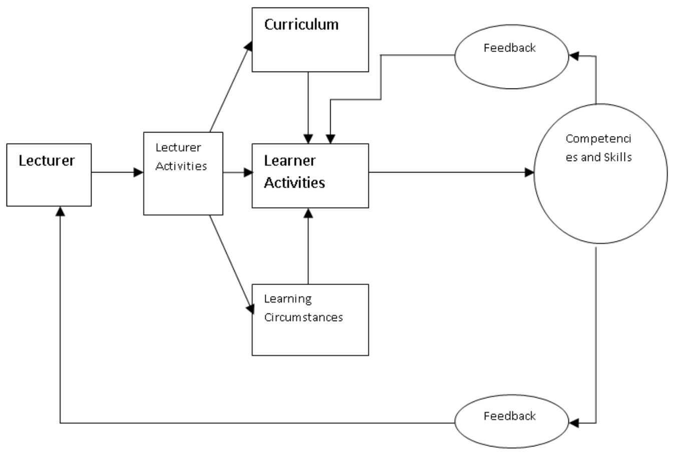

Figure 1: Lecturing-Learning Paradigm

From the learning paradigm as suggested by [8] in the Fig. 1, it can be seen that if all the linkages between the student and the lecturer are severed, the student may still learn though less effectively, through his contact with the curriculum and the learning circumstances such as workshops and laboratories. Curriculum is progressively being seen by stakeholders as a dynamic framework guiding teaching and learning processes and as a steering mechanism for quality [9]. Curriculum relevance is a condition outcome, not only for improving the human capital potential of education and training graduates but also for retaining learners in education and training systems.

It should however be noted that an astute lecturer may influence to a greater extend the attainment of the competency aimed for in whichever course unit. Encouragement should be given to students to learn the competencies identified by their lecturers so that we can move away from the traditional educational system where the unit of progression is time and is lecturer-centred. With the adoption of competency-based training system, the unit of progression will therefore become mastery of specific knowledge and skills and is learner-centred.

Use of this method has shown remarkable improvements in student performance by:

1. exposing students earlier in the curriculum to real-world engineering applications versus the simpler applications which are currently used in microprocessor classes;
2. enhancing co-operative learning which is essential in engineering curricula;
3. satisfying students' practical knowledge by designing mini projects from the specifications given to them early in the semester;
4. facilitates efficient learning of software design techniques in microprocessor systems;
5. making it possible for the students to appreciate the working of the processor registers and memory as are hardware, in simulation form. The approach provides some visualization on the structure and way data is transformed during execution.

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