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Embedded Systems: Teaching and Design Challenges for Nonhomogeneous Classes

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Abstract

The growth of technology leads the industry to move beyond and crosses the boundaries of its own disciplines. The changes from pure mechanical system, to electronics systems and the integration with control software brings new challenges to the engineers working in the industry and to the source shaped the engineers. As a result, institutes of higher education need to make the necessary changes to meet this continuing market demands. This work address the issue and describes a new systematic and an effective approach for teaching hardware based courses for large non-homogenous (Computer Science and Electronics students) class setting using existing e-learning system in the university to promote powerful, long-lasting learning outcomes. It is a blend of several approaches with an insightful goal to provoke deeper understanding in various topics in microprocessors and microcontrollers details, intended to teach the computer science students to learn low-level hardware interfacing, interrupt handling, and other microprocessors issues, as well as embedded systems through learning microcontrollers. Our methodology revolute around three steps: using visual simulators, incrementally weighted exercises, from easiest to hardest, and finally working on real hardware controllers. The proposed approaches developed for the course "Embedded Controller Technology", but any other hardware based course can apply them. The approach comprises a 3-hour a week lecture and 2-hour a week laboratory, both taught in the 3rd semester. Imposing the approach leads to the overall improvement of the course quality: student satisfaction and interest, increased number of completed hardware projects and significant improvement in grade distribution and it has been observed that students feel better prepared to face the challenges to be found in their future professional activities.

Keywords: *Embedded Systems Design, Teaching, Challenges, Web 2.0*

1. Introduction

Recent years marked the digital electronics technological revolution which bringing us the era of smart devices. This advances in digital design technology, result in incredible surge in computational power available in appliances. According to Moore's Law, billions of chips could be produced at low cost and with ever increasing functional capabilities. Yet, the exponential scaling also made the design of these chips much more difficult, requiring a step up into the hierarchy of abstraction levels in order for designers to be able

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to cope with the increased complexity. At the same time, integration of software and hardware aspects has introduced embedded systems.

Known for being everywhere, having become crucial in an industrial context, constantly expanding in both complexity and volume production, consist in the fastest rising market share for computing products, and accounting for the largest number of systems being deployed. Embedded computing has rose as the new paradigm for the design and implementation of modern computer systems, succeeding mainframes, minicomputers, and finally desktop computers. As embedded systems requirements grow in complexity, the need for highly specialized hardware/software platforms becomes more critical and their design cannot be left without a proper education of electronics and/or computer science engineers in this new domain.

In order to accommodate to the industry demands, institutions of higher education had been offering the students. Interdisciplinary courses such as embedded systems. Embedded systems education must be multidisciplinary and cover aspects of control and signal processing, computing theory, real-time processing, distributed systems, optimization and evaluation, and systems architecture and engineering. However, despite the variety of educational approaches used to integrate these courses in their curricula, the institutions face several difficulties and challenges seems be universal when it comes to address the embedded systems such cognitive mind-set. People learn by connection different ideas together. Cognitive scientist verified that learning is a process of drawing connections on what people have already known. Hence, students with different backgrounds will associate the new knowledge differently. As students from different disciplines have different ground courses, they would have different cognitive mind set. [7-8]. Student from different disciplines might have different description for the same term. For example, the word “model” for Computer Science student can mean a software model, while it means a hardware model for the Electronics students.

Teaching students how hardware devices work, what a computer really does when executing a program at the lowest level, and how they can be employed in their designs is often a very challenging process. Students are not very fascinated to know how the computer works, but only to know how they can use it to execute their software solutions. Therefore, the lecturers for hardware courses have to be more engaged than usual during direct contacts with students. Even more, reorientation from computing to software programming certainly spurs students to feel that hardware oriented courses are simply a burden that they have to put up with in order to gain their grade and pass the exam [1]. There are various approaches in teaching computer science students about hardware. [2] presents a method for getting the students hands-on experience on the software and hardware interaction. [3] emphasis on embedded software and systems as part of teaching and learning. [4] presents the experiences while using the simulation in an introductory microcontroller class. In [5] applied a common methods of class room teaching and experimental teaching, with the emphasis on problem-analysis and the problem solving abilities of the students on hardware curriculums. Several methods of active learning are implemented to encourage the interaction between teaching instructor and students, as well as among students. Table 1 shows the active methods that implemented include informal group learning, formal group learning, group working, problem based learning, team teaching, cold calling, in-class demonstration, muddy concept test, and laboratory work [6-10].

Table 1. Active Learning Methods

Method	Description
Informal Group Learning	The instructor will spontaneously break the class into small groups of 2 or 3 students. Each group will discuss a particular topic and the group representative will present the findings in the class. The group may be valid for this discussion only.
Group Work Learning	The Students work in groups in or outside the class to solve a particular problem. Requires co-ordination between the students which presents an opportunity for the students to develop socially as well.
Problem Based Learning (PBL)	Usually conducted in group. The instructor provides an open ended problem and the students will need to discuss ideas or hypothesis that can be used to solve this problem according to the experience and knowledge. The instructor acts more like a facilitator throughout the discussion.
Team Teaching	Two instructors from different field work together to conduct a class at same time to a single group of students. Discussion between the instructors can take place "live" before the students, so they are be able to experience the view from different field.
In Class Demonstration	Instructor uses different objects to explain the subject or to draw students' interest to the subject. The objects may be hardware, chart, tool, or acting the process.
Concept Test	Instructor pose a question that encompass the important concept for the particular class at the end of the class, and the student will hand up its answer at the end of the class. Throughout their answers the instructor will be able to access the students' understanding.
Laboratory Work	The whole class can be conducted in the laboratory

2. Theoretical Background: Web 2.0 in Higher Education

The advent of Web 2.0 technologies has provided new prospects for creating and sharing content and interacting with others. Also called 'social media', Web 2.0 contains tools that allow individual and collective publishing; sharing of images, audio and video; and the creation and maintenance of online social networks. And, it is argued, with these new tools have come new practices and attitudes. Today's learners exist in a digital age. This signifies access to, and use of, a variety of Social Web tools and software that convey gateways to a multiplicity of interactive resources for information, entertainment and, not least, communication. This section, briefly review Web 2.0 and their educational, and motivates the application of social networks namely Facebook in higher education

2.1. What is Web 2.0?

Over the past ten years there has been a growing attraction in the innovative generation of web-based technologies, tools and services under the labels Web 2.0 and social software or social media. The term "Web 2.0" became ubiquitous after the first O'Reilly Media Web 2.0 conference in 2004 and provides now more than 76 million hits in Google. Web 2.0" is a expression that is used to symbolize numerous diverse concepts: Web sites based on a particular set of technologies such as AJAX (autonomous Javascript and XML); Web sites which integrate a robust social component, involving user profiles, friend links; Web sites which motivate user-generated content in the form of text, video, and photo postings along with comments, tags, and ratings; or just Web sites that have gained admiration in recent years and are subject to fevered speculations about valuations and IPO prospects.

Despite the widespread of Web 2.0 a precise definition of Web 2.0 is elusive and there is still an enormous amount of divergence about just what Web 2.0 means, with some people decrying it as a meaningless marketing buzzword, and others accepting it as the new conventional wisdom [11]. Oberhelman [12] notes that "Web 2.0 refers generally to web tools that, rather than serve as a forum for authorities to impart information to a passive, receptive audience, actually invite site visitors to comment, collaborate, and edit information, creating a more distributed form of authority in which the boundaries between site creator and visitor are blurred. Downes [13], consider that the appearance of Web 2.0 is a social revolution rather than a technological revolution. Web 2.0 tools and services develop new modes of connectivity, communication, collaboration, sharing of information, content development and social organization. Bryant [14] believes this novel way of living as the "always on" culture where divisions between learning, working and entertainment are starting to blur.

Although the term Web 2.0 suggests a new version of the World Wide Web, it does not refer to any actual change in technical specifications, but rather to changes in the ways software developers and end-users utilize the Web. Web 2.0 is a catch-all term used to describe a variety of developments on the Web and a perceived shift in the way it is used. This shift can be characterized as the evolution of Web use from passive consumption of content to more active participation, creation and sharing.

Web 2.0 Websites allow users to do more than just retrieve information. Now users can build on the interactive facilities of Web 1.0 to provide "network as platform" computing, allowing users to run software-applications entirely through a browser. Users are able to co-author the data on a Web 2.0 site and exercise control over it. These sites have an "architecture of participation" that encourages users to add value to the application as they use it. This stands in contrast to traditional Websites, which limit visitors to passive viewing and whose content only the site owners can modify. Web 2.0 Websites typically include some of the following features/techniques:

- **Search**: the ease of finding information through keyword searching.
- **Links**: guides to important pieces of information. The best pages are the most frequently linked to.
- **Authoring**: the ability to create constantly updating content that is co-created by users. In wikis, the content is iterative in the sense that the people undo and redo each other's work. In blogs, it is cumulative in that posts and comments of individuals are accumulated over time.
- **Tags**: categorization of content by creating tags that are simple, one-word descriptions to facilitate searching and avoid having to fit into rigid, pre-made categories.
- **Extensions**: automation of pattern matching for customization by using algorithms (*i.e.* Amazon.com recommendations).
- **Signals**: the use of RSS (Real Simple Syndication) technology to create a subscription model which notifies users of any content changes.

Critics of Web 2.0 maintain that it makes it too easy for the average person to affect online content, which can impact the credibility, ethics and even legality of web content. The extent of data sharing and gathering also raises concerns about privacy and security. Defenders of Web 2.0 point out that these problems have existed ever since the infancy of the medium and that the alternative -- widespread censorship based on ill-defined elitism -- would be far worse. The final judgment concerning any web content, say the defenders, should be made by end users alone. Web 2.0 reflects evolution in that direction [15].

2.2. Web 2.0: Learning Concepts

Web 2.0 is difficult to define because it is not really a thing, but an approach, or shift, in how we use the Web we already have. The key is a change to a more active user who actually creates content rather than just passively receiving it. This change in how we experience the Web mimics a parallel shift occurring in education. Instead of a top-down, “sage on the stage” approach to teaching, we are moving towards a more constructivist, “guide on the side” pedagogy which empowers students and encourages them to take responsibility for, and co-create, their learning experience.

Young people seem to be particularly attracted to Web 2.0 developments, often for the social aspects of easy communication, coordination, and online self-expression. Web 2.0 innovations harmonize well with current thinking about educational practice. In particular, Web 2.0 offers student’s new opportunities to take more control of their learning and create customized information, resources, tools, and services. Web 2.0 also encourages a wider range of expressive capability, facilitates more collaborative ways of working, enables community creation, dialogue and knowledge sharing, and creates a setting for learners to attract authentic audiences. Any educational practice that concerns the playful, expressive, reflective or exploratory aspects of knowledge building is likely to find web 2.0 tools and services a powerful resource. When directed at learning, web 2.0 impacts on four principal dimensions of the learner’s experience. Two are broadly social in nature (collaboration and publication) and two are more cognitive (literacies and inquiry) [15].

- **Collaboration**: Web 2.0 services support communication. They let learners to manage their activities to several degrees of depth. This can range from the relatively minor level of participating in anonymous recommender systems to the more intense level of interpersonal, verbal debate. Web 2.0 may offer educators a set of tools to support forms of learning that can be more strongly collaborative and more oriented to the building of classroom communities.
- **Publication**: We expect to see the work of learners on display in a classroom. The read-and-write character of web 2.0 supports users in creating original material for publication. Its relatively unbounded space can offer a strong feeling of doing authentic research when students can publish and discuss the products of their study.
- **Literacies**: Culture stimulates a form of intelligence that is ‘literate’. Schooling cultivates a distinct orientation towards language, to which interactions with writing are crucial. Digital media stretch this tradition by offering new modes of representation and expression. Even the term ‘literacy’ now has to be stretched to admit other forms of representational fluency than those associated with the printed word. As learners engage with digital artefacts through web 2.0, so the curriculum must address the challenge of developing their confidence with new literacies and their increased potential for creativity.
- **Inquiry**: Web 2.0 technologies offer new ways for learners to conduct personal research. It creates new structures for organizing data, new sources to refer to, new forms of authority, and new tools to interrogate this rich space of information. All of this has the potential to empower the student as an independent learner. But it also brings challenges to both learner and teacher. Web 2.0 knowledge structures are not navigated with the same tools or the same ease as more traditional documentary collections. It poses problems of authority and the ephemeral nature of web ‘knowledge’.

Web 2.0 tools seem to reinforce vital aspects of learning that may be problematic to stimulate in learners. There are problems with web 2.0 learning in practice, but these tools do seem to mark a step change in the ways in which learners can interact with and on the web. Alongside business, journalism and medicine, it is therefore perhaps not too fanciful to talk of 'education 2.0' [15].

2.3. Web 2.0: Educational Context

The evolution of the web has been a key driver of educational change and offers new perceptions and challenges to education at all levels. It is suggested that Web 2.0 supports constructivist methods to learning and has pronounced potential to socialize online learning to a greater extent than we have previously seen. These tools and services can support much flexibility in the learning processes and allow for easy publication, sharing of ideas and re-use of study content, commentaries, and links to related resources in information environments that are managed by the teachers and learners themselves. Web 2.0 is well appropriate to active and meaningful learning and collaborative knowledge building.

Web 2.0 is appropriate for educational and lasting learning purposes in our knowledge society, because our present society is built to a large degree on digital environments of work and social communication, and educational practices must foster a creative and collaborative engagement of learners with this digital environment in the learning process. However, open educational practices require a decisive shift away from the teacher-centered knowledge-transfer model and highlight active, constructive and the collaborative engagement of students with authentic and complex real world problems. A new educational culture and mind-set as well as overcoming considerable organizational barriers are important prerequisites for that.

The implementation of Web 2.0 technologies in higher education is still a new phenomenon and its incorporation into teaching and learning is in the early phase. The report Open Educational Practices and Resources. OLCOS Roadmap 2012 [16] which is based on research work, expert workshops and other consultations with many international projects that promote the creation, sharing and re-use of open educational resources, concludes that "new educational approaches are not easily found and their implementation will be difficult if they require considerable transformations of current educational frameworks and practices". The current emphasis in education is mainly on providing access to more content in digital formats and there is little consideration of whether this will promote real innovation in teaching and learning.

It is suggested that an area which can make education and lifelong learning more effective and efficient is e-learning. Unfortunately, there has been a tendency for many e-learning models just to imitate previous educational paradigms [16]. However, the growth of the open source movement and social networking, and use of new web-based tools and services among a new generation of students has questioned the previous models of e-learning. To highlight new developments in e-learning based on Web 2.0 and social networking the phrase "e-learning 2.0" was coined by Downes [13] who believes that this new world of e-learning reflects very much the ideas of "a community of practice" suggested by Wenger [17]. In this model, students form networks according to their interests, they collaborate and learn together, they develop and share content using various tools and resources, and re-use and organize content according to their preferences and needs

3.0 Learning Theories and Frameworks

This section focuses on the theoretical fundamentals that shaped and guided this work. Our study is backed by some theories in education. We review them in the following subsections to introduce the background of this work. Section 3.1 presents the learning theory which is the foundation of our work. The framework for cognitive apprenticeships is described and research studies where cognitive apprenticeships have been used as a teaching strategy are reviewed in Section 3.2. The literature review follows with studies that have been conducted in higher education settings using studio baes learning as a means for teaching in Section 3.3. Section 3.4 explores the incorporation of blended learning strategies that take into account educational studies that have explored the impact that different instructional strategies may have on educational outcomes and finally the social learning model is presented in Section 3.5.

3.1. Learning Theory

In psychology and education, learning is commonly defined as a process that brings together cognitive, emotional, and environmental influences and experiences for acquiring, enhancing, or making changes in one's knowledge, skills, values, and world views [18-19]. Learning as a process focuses on what happens when the learning takes place. Explanations of what happens constitute learning theories. A learning theory is an attempt to describe how people and animals learn, thereby helping us understand the inherently complex process of learning.

Learning theory [20] is the foundation of this research, which supports all the learning processes, and is used to guide the design of learning systems. Learning theory is a framework that describes how information is absorbed, processed, and retained during the learning process. There are three main categories of learning theory including behaviorism, cognitivism, and constructivism as shown in Figure 1.

Behaviorism emphases on achieving the objectively observable behavior by repetition of desired actions. Cognitivism looks beyond behavior to explain how the learning happened in our brain. Constructivism views learning as a process in which a student actively constructs or builds new ideas or concepts.

This work is developed based on the constructivism learning theory. Constructivism learning theory [21, 22] needs students to construct knowledge in their own meaning, to build up knowledge concepts based on prior knowledge and their experience, to enrich their learning through social interaction, and to develop learning through authentic tasks. During Constructivism learning, students achieve learning outcomes by attempting to address problems when they find their expectations are not met, so they need to resolve the discrepancy between what they expected and what they encountered [23].

In the learning theory of constructivism, each student is considered as an unique individual with personalized needs, learning styles, learning preferences, knowledge levels and knowledge backgrounds, which is complexity and multi-dimensional. In the constructivist session [21], students work on problems, and might suggest diverse responses to learning, *e.g.* they are involved in an active learning process, and teachers only mediates to guide them in the right direction. Students use critical thinking to challenge, judge knowledge, and learn from it. Whereas the teaching methods are deliberate according to these learning outcomes. With the help of techniques in e-Learning, the learning process, which emphasizes that knowledge is shared between teachers and students, does not focus on the teacher-centered learning environment, but put more emphasizes on self-paced learning by providing access to education at any time, any place and taking into account students' differences.

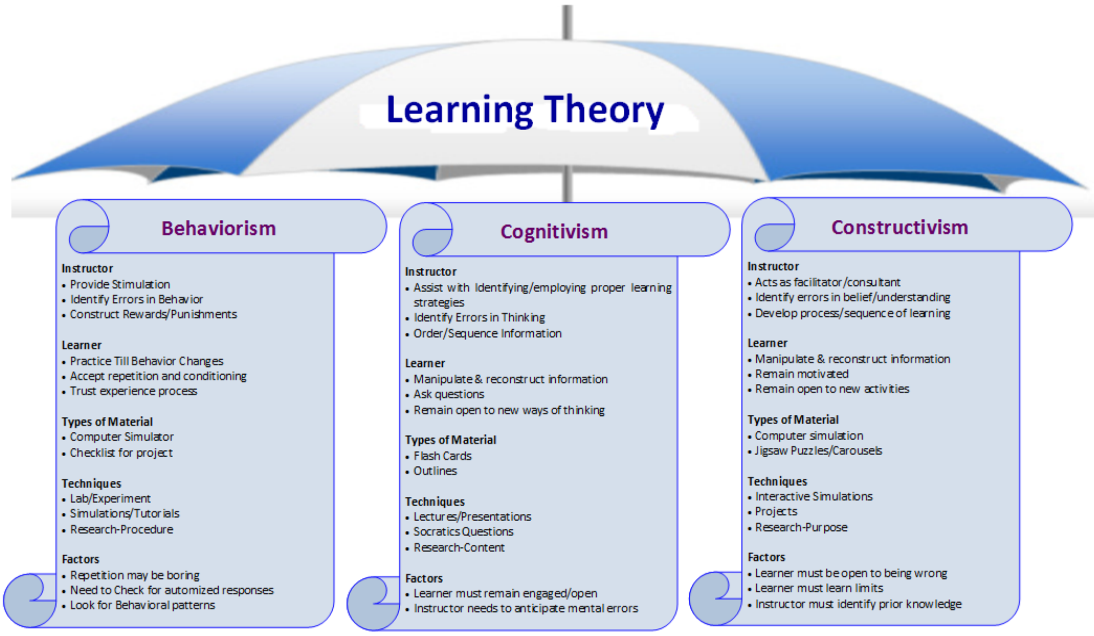


Figure 1. Learning Theory

3.2. Concepts of Cognitive Apprenticeships Learning Theory

The term, 'cognitive apprenticeship', "denotes to the application of the learning-by guided-experience on cognitive and metacognitive, rather than physical skills and processes" [24], and is used to describe classroom instruction merged with apprenticeship characteristics. A major advantage of learning by cognitive apprenticeship as opposed to traditional classroom-based methods is the opportunity to see the subtle, tacit elements of expert practice that may not otherwise be explicated in a lecture or knowledge-dissemination format. Cognitive apprenticeship has become one of the recognized models to support learning and has gained respect and popularity throughout the 1990s and into the twenty-first century [25].

The method of a cognitive apprenticeship teaching model suggests that the learning relationship between the student and the teacher will last longer as compared to more traditional relationships within today's classroom environment. It also implies that the teacher is an expert in the field in which the student is learning [26]. In order to apply the cognitive apprenticeship model as an instructional technique, Collins [27] recommend that teachers must:

- "Determine the procedures of the task and make them clear to students;
- Put abstract tasks in expressive contexts, so that students understand the relevance of the work; and
- Vary the variety of situations and articulate the shared aspects so that students can transfer what they learn".

Number of studies have been developed analyzing the implementation of a cognitive apprenticeship approach in a computer science courses. Mow, Wing, and Yates [28], for example, showed that students significantly improve their learning with a cognitive apprenticeship-based approach, their study was developed with a quasi-experimental design, with non-equivalent groups and only a post-test, plus an evaluative questionnaire to measure student satisfaction. Comparing student grades, their results indicated that the group (with cognitive apprenticeship) perform better than second group (without cognitive apprenticeship). Vihavainen *et al.*, [29] design an extended cognitive apprenticeship model, which they named Extreme Apprenticeship (XA), and applied it to a computer system course. Their model is based on cognitive apprenticeship plus an added and strong emphasis on developing guided programming exercises. As Vihavainen *et al*. [30] noted, a slightly-guided instructional strategy does not work well for complex cognitive learning such as computer programming [31] and for this reason, they decided to expand cognitive apprenticeship in this way. Vihavainen *et al.*, [30] compared the final grades of students in non-XA courses offered to students over an eight-year period, with the final grades earned by students in one year of XA-modified courses. Their result indicated significant improvements in performance in terms of student grades after they applied their proposed model.

There are several sameness and variances between traditional and cognitive apprenticeships [24]. Cave [59] describes that the similarities between both models relate to learning arrangements. She describes that students are stimulated to deal with authentic tasks and learn through observing others during task completion. Students have to entirely involve in the events with assistance from experts. On the other hand, establish three significant differences between traditional apprenticeships and cognitive apprenticeships. They reveal that the traditional model is more observable since students are engaged in physical activities, such as wood carving. Cognitive apprenticeship, however, needs students to learn knowledge and skills that are not inevitably evident to the eye, for example a lesson is typically presented in text, video or online. Second, the traditional apprenticeship method to learning is limited fully to the workplace. Learners manage to make direct associations between the task and the finished product. On the contrary, learning in cognitive apprenticeships is modeled in real-world situations [32]. Teachers have to design learning activities for use within the school curriculum in contexts that make sense to students. The problems and tasks that are assigned to learners in cognitive apprenticeships arise not from the demands of the workplace but out of pedagogical concerns [32]. Third, learners in traditional apprenticeships require less transfer of skills, given that the skills to be learned are inherent in the task itself. In contrast, cognitive apprenticeships demand that students transfer what they learn through reasoning, diagnosing problems and explaining their thought processes. Table 2 summarizes the differences between traditional apprenticeships and cognitive apprenticeships.

Table 2. Differences Between Traditional Apprenticeships and Cognitive Apprenticeships

Traditional Apprenticeship	Cognitive Apprenticeship
Simple tasks	Complex tasks/Problem-based
Physical skills and processes	Cognitive and metacognitive processes
One-on-one learning in the workplace	Learning with several students in the classroom and laboratory
Tasks performed by observation	Tasks and processes performed by reasoning
Learning by doing physical tasks	Learning by externalising thought processes in diagnosing problems
Learning from modelling, coaching and fading (slowly removing scaffolding as students develop competence)	Learning from modelling, coaching, scaffolding, articulation, reflection and exploration of ideas
Job determined by tasks	Learning determined by outcomes

In order to transform the model of the traditional apprenticeship to the cognitive apprenticeship, Collins *et al.* [24] propose that teachers find ways to transfer implicit processes into explicit processes, thus allowing students to detect, perform and practice with help from the teacher. They suggest six characteristics of cognitive apprenticeships:

modeling, coaching, scaffolding, reflection, articulation and exploration as guidance for teaching and learning. These characteristics assist students to familiarize and assimilate into authentic practices [33]. Within these authentic practices, students are exposed to the principles of legitimate peripheral participation [34]: also reciprocal teaching [35], in those students as novices collaboratively involve themselves in social interactions with more knowledgeable other to increase their understanding and become proficient. Figure 2 illustrates and summarizes the model of cognitive apprenticeship adapted from Brill *et al.* [36].

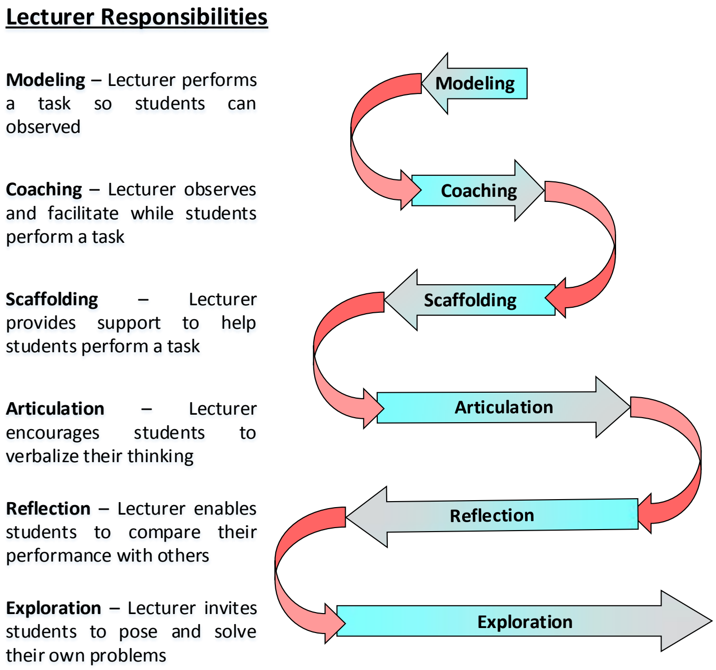


Figure 2. Cognitive Apprenticeship Characteristics

3.3. Studio Based Learning: Theoretical Context

Studio-Based Learning (SBL), adapted from architectural education by Hundhausen, *et al.* [37], is an approach applied to the teaching and learning computing that emphasizes the iteration of the skills of computational thinking, critical analysis, collaboration, and communication. Students solve complex design problems collaboratively and present their solutions to peers and instructor(s) for review followed by revision(s) reflective of the review process.

The concept of Studio-Based Learning has been used under different names since the 1800s in the U.S. to refer to a collaborative, mentoring, hands-on approach to teaching and learning. The strategy, in early implementations, focused on master-apprentice relationships in skill training and the arts. Other names, for similar approaches throughout the educational history of the U.S. include the Quincy Systems and the platoon system. The platoon system recognized the role that community played in motivating achievement, a defining characteristic in the Studio-Based Learning strategy describe in Lackey, J. [38].

Studio-Based Learning evolved from previous studies of the socio-cultural constructivism thread of constructivist learning theory. Principle elements from these previous works included learning by doing, collaborating with the environment (other students, instructors, and external stakeholders), and re-doing until an agreement was reached among stakeholders. As applied to programming projects, this means that the design, output, structure, source code, and other goals were met or exceeded.

The expression Studio-Based Learning (SBL) is meant to define a general methodology to interaction with students that is instructor facilitated, student centered, and hands on. When an audience is asked to describe what they do in a lecture hall, they invariably suggest activities such as: listen, take notes, chat, sleep, read, and so on. When asked what they think might happen in a studio they usually suggest: paint, draw, sculpt, write, and other active pursuits. The difference is clear. The focus in a lecture hall is on the work of the instructor. The focus in a studio is on the work done by the student. That is indeed the key distinction [39]. Hence, the studio-based learning (SBL) model aims to promote learning in a social and collaborative context [40].

Moreover, Myneni [41] defined studio-based learning (SBL) as an instructional technique that emphasizes collaborative, design-oriented learning. He also added that this pedagogy is not new; it dates back to old architectural schools where they have practiced this in the form of design studios where (a) students created their own work spaces, (b) students worked in groups to solve problems, and (c) students presented their solutions to the class to obtain feedback from their instructors and also from their peers.

Studio-Based Learning is differentiated from project based learning in several significant ways. First, group responsibilities are required. One of the fundamental objectives is to build a sense of community resulting in a support group that improves all students' levels of knowledge and performance. Loyalty to the group is a powerful motivator for students to persevere to project completion. Second, students are required to present solutions to peers for review. In project based learning, the audience is an optional component. Third, peer evaluation and revision using the process improvement loop is a required component of SBL. Groups must understand and apply critical feedback as demonstrated by improved product after revision.

Project selection for SBL is a critical component for success. The students have no input into the project selection as it is specifically designed to (1) teach fundamental CS concepts necessary to proceed to subsequent more complex concepts; and (2) be of sufficient complexity to challenge a group of students to exercise problem-solving skills in the process. Problem selection is critical, and, if done right, will initially result in short-lived gnashing of teeth among students. If the problem is too complex, students are unlikely to solve the problem adequately or to experience the sense of accomplishment that comes from successfully applying problem solving and critical thinking skills. If the problem is too simple, then problem solving and critical thinking skills are not called into play to successfully complete. "Just right" problems require students to practice and improve problem solving and critical thinking skills. Students are allowed to decide, through collaboration, the "role" they will play in the ultimate solution.

3.4. Blended Learning Approach

Blended learning is often defined as the combination of face-to-face and online learning [42] as illustrated in Figure 3. Ron Bleed, the former Vice Chancellor of Information Technologies at Maricopa College, argues that this is not a sufficient definition for blended learning as it simply implies "bolting" technology onto a traditional course, using technology as an add-on to teach a difficult concept or adding supplemental information. He suggests that instead, blended learning should be viewed as an opportunity to redesign the way that courses are developed, scheduled and delivered in higher education through a combination of physical and virtual instruction, "bricks and clicks" [43]. The goal of these redesigned courses should be to join the best features of in-class teaching with the best features of online learning to promote active, self-directed learning opportunities for students with added flexibility [44]. This sentiment is echoed by Garrison and Vaughan [45] who states that "blended learning is the organic integration of thoughtfully selected and complementary face-to-face and online approaches and technologies" as shown in Figure 3.5. A survey of e-learning activity by Arabasz, Boggs & Baker [46] found that 80 percent of all higher education institutions and 93 percent of doctoral institutions offer hybrid or blended learning courses.

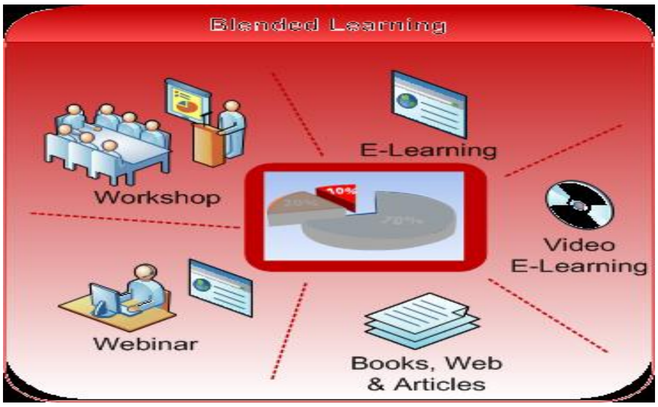


Figure 3. Blended Learning

Education had shown the positive effects. According to Abraham [47], recent research had successfully exposed the benefits of blended learning which are:

- Critical thinking can be fostered
- The effectiveness of online assessment system and computer tutorials will be encouraged.
- Students may have more control over their learning.

Research conducted by Fatimah *et al* [48] had very a positive feedback from the respondents. The research was conducted to identify their perceptions towards blended learning in learning Mathematics in higher education in the topic of application of integration. Their perceptions towards blended learning approach are:

- Courseware used can make the learning process become easier.
- Method used allowed learners to learn the topic better compared to the usage of textbook.
- Important concepts can be visualized easier.
- Enhance the learners' abilities to analyze better.
- Appreciation on online integration can be promoted
- Mathematics will be learnt in interesting way.

In another research, the benefits of blended learning are discovered. They are stated as follow:

- Students' initiative and incentive in learning will be encouraged.
- Learners' abilities, skill and potential can be explored by educators (Lau *et al*, [49])

Blended learning environment is seen to be one of the best learning environments that can be implemented when its advantages are considered. However, other learning approaches should also be revised and considered to complement blended learning as well as to ensure the effectiveness of teaching and learning process.

3.5. Social Learning Model

E-learning has been widely used in universities and higher education institutions as a supplement to the traditional face-to-face classroom learning environment as well as in the continuing education and distance education institutions (Tetiwat, O. & Igbaria, M., [50]). The e-learning is a complex system that includes distance teaching and learning, separated in time and space, as well as teaching materials that can be in various forms, the individual or group learning process, the tutorial and interactive work (Despotović, M. &

Radenković, B., [51]). It is an interactive process between teachers and students through electronic media with an emphasis on learning, as the media are just an additional tool that complements the process.

Nicholson described that the e-learning has now been shifted into a new generation that focuses on more learner engagement and social learning and provides learners with collaborative and learner-centered online learning environments (Nicholson, P.A, [52]). This new e-learning platform is called e-learning 2.0 or "social learning" (Yau, J., Lam, J. & Cheung, K.S., [53]).

Social learning or "E-learning 2.0" presents an online environment emerged from the development of Web 2.0 (Chow, K.O. & Cheung, K.S., [54]). Web 2.0 is not a technology, but an attitude and social revolution which enables and encourages learners to participate in a socially open environment with rights of content creation and edition [53].

Five broad characteristics of Web 2.0 were identified (Duffy, P., [55]). First, Web 2.0 is a platform that allows users to access and use via Internet. Second, it has a user-friendly and interactive interface. Third, its design encourages users to participate and publish ideas in it. Forth, it is a social networking tool that enables users to provide feedback and exchange ideas collaboratively. Last, users have content ownerships in the site and rights to control over them. In other words, Web 2.0 represents ideas of learner-centered, collaborative and interactive learning [53].

By linking the ideas of Web 2.0, e-learning 2.0 is characterized by learner-center, content access and content creation. To facilitate learner-centered learning, e-learning 2.0 encourages learners to actively interact with other users in the learning process by using technologies such as social media tools. E-learning 2.0 emphasizes open communication, freedom for sharing, social networked learning and socially constructed knowledge [54]. Social learning implies that:

- Informal/social learning is integrated in formal learning;
- Learning community is built which includes not only students and facilitators, but also peers worldwide;
- Students build their own e-Portfolios and Personal Learning Environments;
- The Learning Management Systems (LMS) are enlarged by using Free and Open Source Software (FLOSS), Open Educational Resources (OER), collaborative content and interactions on Web2.0 platforms/applications, such as blogs, wikis, RSS, podcasts.

In pedagogy, Social Learning means learning through social interaction between peers. With the growth of Social Media, Social Learning is understood as learning with Social Media, through communication and collaboration, with peer learners, and possible with facilitators [56]. Social media can be incorporated into the formal e-learning content to create formal social learning; this can be done in 3 different ways wrap-around model, integrated model, and collaboration model (Jane Hart [56]) as shown in Figure 4.

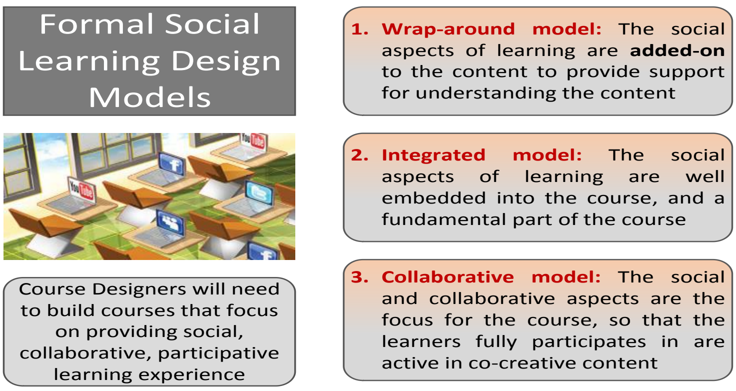


Figure 4. Social Learning Models

However, Jane impresses that, the wrap-around model won't work that well, it will be like the early days of e-learning when online learning was bolted onto formal courses, it just was not used! Social aspects need to be well integrated into a course to ensure that they are an integral part of it as express by the integrated model, but furthermore a collaborative approach, where the course is focused around working together rather that the content itself; it is a very effective model.

4.0. The Proposed Courseware Structure

This section describes in detail the proposed study's research design and the main methodological choices made. It gives description to the course's as the main objective is for the students to obtain a clear understanding of issues such as low-level hardware interfacing, handling of interrupts, communication between controller and peripheral devices trough learning the basics of controllers and its instruction set, as well as embedded systems through learning microcontrollers.

At Universiti Malaysia Pahang (UMP), Faculty of Electrical and Electronics Engineering one of the leading public University in Malaysia, Embedded Controller Technology has been used as practical study cases to teach embedded system theory and practice in an undergraduate, one-semester course, offered as part of the Electrical and Electronics Engineering Bachelors curriculum. The course is internally referred to as BEE4323. The core objective of this course is to teach hardware, software, and system design in an embedded system context. Students are allowed to take this course only after a series of prerequisites is met, which give them a solid background on digital logic, microprocessor, and C language programing. Students typically enroll for this course in their 4th year of studies. The practical projects used in the course are based on fundamental tasks ranging from simple to complex such as up/down counter, traffic light, temperature monitoring, and gas detection. The adopted algorithms are implemented as embedded systems based on 68HC11 microcontroller, with students being asked to achieve a set of goals for each problem, as defined by the assigned instructor.

In terms of supervised teaching, the course teaching is spilt in two parts: theoretical lectures with 2 classes per week, and practical exercises with 2 classes per week in laboratory. However, students spend significantly more time developing their chosen projects out of classes, receiving help from instructor whenever necessary. Lectures are organized in larger groups, while practical exercises are carried out as a project in microprocessors/microcontrollers laboratories in groups of up to 2 students/group, with one group working on one workstation. During the semester, the course is divided in two parts. The first part covers the introduction to embedded systems, 68HC11 microcontroller architecture, addressing modes, instruction set architecture, stacks and subroutines, and the interrupt handling system. The second part of the course focuses on interfacing 68HC11 with elementary peripherals such as LEDs, switches and seven-segment display, Timers, Analog/Digital converter (ADC), Pulse width Modulation (PWM) as well as building an small scale embedded system [57].

The assessment of the course was done continuously throughout the semester based on coursework and final exam. Assessment of coursework was based on the quiz and assignment projects. Coursework is counted for 60% of the final mark with 40% for final examination as shown in Figure 5.

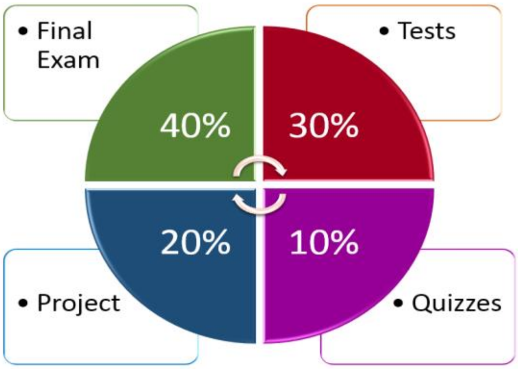


Figure 5. Course Marks Distribution

I gave a lecture every week covering the syllabus topics and assigned students to complete the tasks as described in the proposed courseware and design structure illustrated in Table 3. [58]. The developed courseware includes 11 teaching modules that cover different aspects of embedded system design. These modules emphasize the balance between theoretical foundations and technical practices of embedded system design. Each module can be taught in one or two lectures, depending on the content of the module and students' background.

Table 3. Course Structure for Courseware and Web-Based Multimedia Design

Week	Syllabus Topics (Classroom Lectures)	Task	Phase
1	**Introduction to the course, tasks, the policy of class attendance, and Student responsibilities** **Introduction to Embedded Systems** • Definition of Embedded System • Embedded System vs General Computer System • Element of Embedded Systems • Embedded System Classification and Major Application • ASICs and PLDs		**Phase 1:** **Week (1-5)** Modelling, Coaching, and Scaffolding by tutor and peers
2	**68HC11 Microcontroller Architecture** • Programmer Model • Operating Modes • General Purpose and	Students have to form a project team (not more than 2 students) for their class project (Design of Embedded System).	

	Domain Specific Processor • Microcontroller Selection (Speed, Memory, I/O Interfaces)		
3	**Embedded System Programming (Assembly and C)** • 6811 Assembly language Programming • Introduction to THRSimII Simulator • Introduction to C for Microcontroller • Software Development & Debugging Processes, Function and libraries.	Students have to set-up their own project, *e.g.* project goal, description, and desired outcome	
4	**Addressing Modes and Data Processing Instructions** • 6811 Addressing Modes • 6811 Instruction Set Architecture (Arithmetic, Logic, Bit Manipulation, Shift & Rotate) • Program Control Instructions	Microprocessor Lab begins: Learn THRSimII Simulator	
5	**Stack and Subroutine** • Stack defection and Application • Subroutine Concepts • Call and Return Instruction • Parameters Passing	Design Simple 68HC11 Assembly program using THRSimII	
6	**Interrupt** • Interrupt Vectors • Maskable and Non-Maskable Interrupt • 10.3 RESET, IRQ, XIRQ, SWI, Other Interrupts	Discuss the project in depth: Software design and Determine the required components for the hardware design.	**Phase 2** **Week 6** Articulation, Reflection, exploration

	Sources		
7	**Timers** • Basic Timer and TCNT Register • Timer Overflow and Timer Interrupt • Output Compare and Input Capture • Real Time Interrupt • Pulse Width Modulation • Computer Operating Properly (COP)	Design a power supply circuit, Clock circuit, and RESET circuit for the 68HC11 processor 68HC11 free running test	**Weeks (7-10)** Coaching and scaffolding by instructor and peers
8	**Analog Input and Output** • Operation of M68HC11 A/D Converter • Initialization, Setting and Interfacing	**First Submission on eLearning (KALAM)** Post the software design on KALAM and explain the design concepts	
9	**Memory Interfacing (Expand Mode)** • Memory Types • Interface Circuit Design • ROM and RAM Interfacing	**On eLearning KALAM** Students have to constantly reflect, compose and recompose their design with help of other through coaching and scaffolding	**Weeks (8-9)** Articulation, reflection, exploration
10	**Elementary Input/Output Interfacing** • Elementary I/O • LED Interfacing • Switches Interfacing • 7-Segment Display Interfacing	**Second Submission on eLearning KALAM:** Students continue to refine and post their second software design Interface the 6264 RAM and 2764 ROM with the processor	**Weeks (10-13)** Exploration
11 & 12	**DC Motor** • DC Motor, Stepper Motor, and Servo Motor • Interface DC Motor with 6811	Interface the input/output peripherals with the processor Download the software hex file onto the ROM and execute by pressing the RESET switch	
13	**Discussion on Embedded**	**Third submission on eLearning**	

	System Design	**KALAM:** Students have to post their Embedded System Design on KALAM	
14	**Discussion on Embedded System Design**	Student have to justify the strength and weakness of their design They have to leave the design on KALAM. This allow them to continuously reflect on their work and experiences in producing better design	**Phase 4** **Week 14** Conclusive articulation and reflection
15		Report Submission and Presentation	

The first phase began with modelling, where theoretical concepts of 68HC11 microcontroller such as architecture, programmer model, addressing modes, instruction set architecture (ISA), assembly language programming, and THRSimII simulator are delivered. In the second phase the students were requested to develop and post their interface design on eLearning (KALAM). In this phase students had to post their designs in three submissions according to a set of dates. This was the phase where their compositions of design were viewed and reviewed through a series of discussions with fellow colleagues and instructor. Their designs were left published in eLearning (KALAM). In the third and final phase of this courseware model: 'conclusive articulation and reflection' - students had to make justifications (final reflective report) for what they had achieved throughout the development of their interface design. They had to reflect upon the strengths and weaknesses of their interface design.

Accompanying the teaching modules, hands-on laboratory and projects on embedded systems development are emphasized. The real labs and projects are based on a Motorola's simple yet elegant architecture, Effective balance of low cost and moderate computational performance and popular in automotive and education MC68HC11 microcontroller chip. MC68HC11 is an advanced 8-bit MCU with highly sophisticated, on chip peripheral capabilities. It has more than 300 instructions, two 8-bits accumulator noted as ACCA and ACCB. They can be used by some instructions as a single 16-bit accumulator called the ACCD register, which allows a set of 16-bit operations even though the CPU is technically an 8-bit processor. In addition it has two 16-bit index register called IX and IY, one 16-bit stack pointer (SP), one 16-bit program counter (PC) and one 8-bit condition code register (CCR). New design techniques were used to achieve a nominal bus speed of 2 MHz. In addition, the fully static design allows operation at frequencies down to dc, further reducing power consumption. The HCMOS technology used on the MC68HC11 combines smaller size and higher speeds with the low power and high noise immunity of CMOS. On-chip memory systems include 8 Kbytes of read-only memory (ROM), 512 bytes of electrically erasable programmable ROM (EEPROM), and 256 bytes of random-access memory (RAM). Major peripheral functions are provided on-chip. An eight-channel analog-to-digital (A/D) converter is included with eight bits of resolution. An asynchronous serial communications interface (SCI) and a separate synchronous serial peripheral interface (SPI) are included. The main 16-bit, free-running timer system has three input-capture lines, five output-compare lines, and a real-time interrupt function. An 8-bit pulse accumulator subsystem can count external events or measure external periods [57].

5. Course Project Implementation

The aim of the project is to achieve skills in designing embedded systems. The project was supported by the tutorials prescribed with the class homework. All projects were required to be done in student groups of no more than two. Each project must include both hardware and software components and it must utilize the touch panel LCD for user interaction, Digital thermometer, Motion Sensor *etc.*, for which students had to work out by themselves how to control and use them. They often had to fight memory and processing limitations of the microcontroller, compared to the high performance of the x86 microprocessors. Students submit their project proposals by the end of the first month in the semester and they receive feedback on design alternatives, solution selection process, setting realistic design specifications.

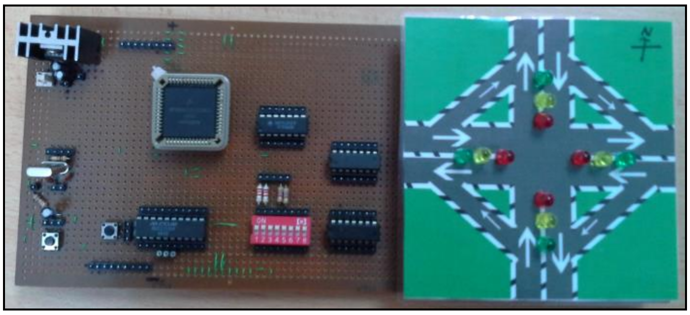


Figure 6 Traffic Light Control Circuit

Provide a choice for non-compulsory projects, all projects were selected from the student real life, such as reading temperature, traffic light control circuit shown in Figure 6, lift controller as shown in Figure 7, and washing machine controller illustrated in Figure 8. As project deliverable, the students were mandatory provide an oral presentation, project demonstration, and written project report. The project activities generated pronounced level of enjoyment among the students and improved their vision in their approaches. In a little cases, students had to change their project from initially proposed ideas, because of facing technical issues in working with some I/O ports that enough resources and/or technical support was not available for.

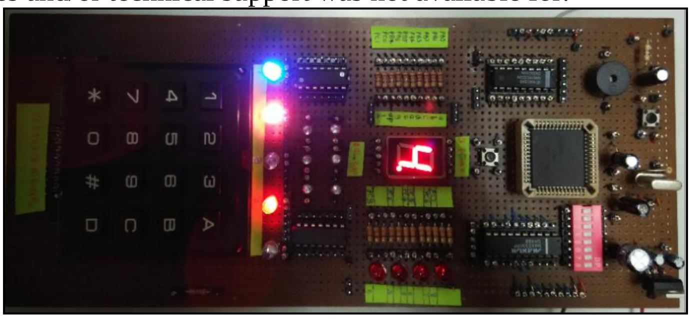


Figure 7 Lift Control Circuit

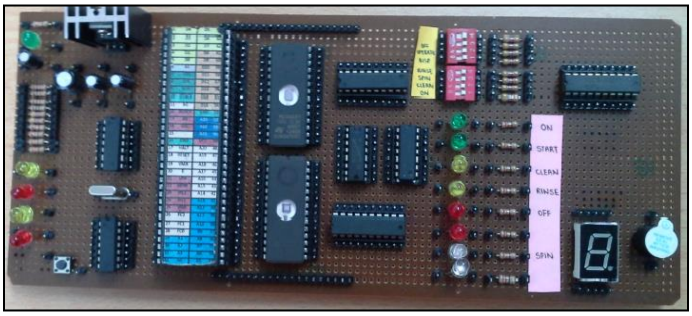
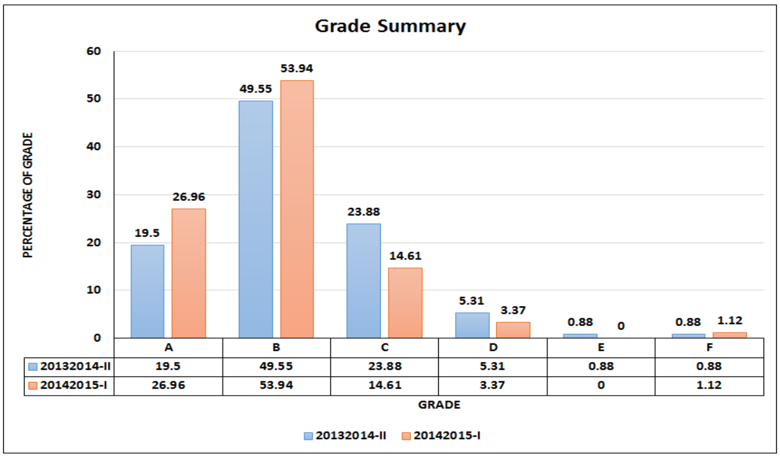


Figure 8. Washing Machine Control Circuit

6. Results and Analysis

This course has been taught at Universiti Malaysia Pahang for more than 20 years. However, with the introduction of the proposed courseware, we can clearly observed significant positive changes on the students' performance in terms of completing their project on time, grading, and achieving the course program outcome. In term of project completion, more than 87% of the students submitted their projects on time, compared to 62% from last year. Figure 9 illustrated the student grades performance for the last two semesters namely 20132014-II and 20142015-I. Comparing student performance for semester 20132014-II and semester 20142015-I, it is clear that the number of student obtained grade A and grade B increased from 19.5% to 26.96% and 49.55% to 53.94% respectively. The number of student obtained grade C and grade D decreased from 23.88% to 14.61% and from 5.31% to 3.37% respectively. No student obtained grade E in semester 20142015-I compared to semester 20132014-II with one student failed in semester 20142015-I because he missed his final examination. This result show that students valued the integrative nature of the projects, where computing was blended with traditional engineering.



	A	B	C	D	E	F
20132014-II	19.5	49.55	23.88	5.31	0.88	0.88
20142015-I	26.96	53.94	14.61	3.37	0	1.12

Figure 9. Students Grade Summary

7. Conclusion

This paper shown a new pedagogical teaching and learning model to teach embedded systems based on microcontroller. Specifically MC68HC11E9 and related simulator and programmer are used so that students can implement systems with hardware and software components. The proposed method is implemented for improving students learning in embedded system and preparing students for tomorrow's embedded system workforce.

The main challenge focused in this work is that students came from different background and have different cognitive mind set. A vital feature of the methodology is the integration between teaching and related research activities, which has permitted the development and testing of relatively complex projects, not otherwise achievable using standard textbooks. Although this is a limited implementation of the proposed approach, collected data show that some satisfactory results have been attained. That is revealed by increased number of completed hardware projects and significant improvement in grade distribution and it has been observed that students feel better prepared to face the challenges to be found in their future professional activities, which is obviously very positive and has encouraged the authors to refine and continue using this approach described in this paper. Future work includes how to disseminate the developed courseware to support broader adoption and evaluate its results.

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