Int. J. Engng Ed. Vol. 19, No. 5, pp. 747–753, 2003
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Application of Problem-Based Learning in an Engineering Course*

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The usual way of learning technical knowledge about a microcontroller (MCU) is by reading relevant handbooks and textbooks. This method requires students to memorize many technical terms and usually ignores its actual application of the data. In this paper, a new approach is proposed using the problem-based learning technique to convey such engineering knowledge. A creative group project was designed for the class whereby students were required to develop their own way of designing a calculator using MCU. Throughout the project, they acquired self-learning techniques to tackle new problems. Moreover, problem-based learning provided students with a cooperative learning environment to enhance their learning capabilities.

INTRODUCTION

NOWADAYS, more and more microprocessors are employed in modern controllers, based on digital techniques rather than traditional analog circuits. Networks of such controllers are very commonly used in building automation systems [1]. Programmable logic controllers (PLC) are microprocessor-based devices designed to replace sets of relays for controlling sequencing in industrial processes. A new study area called Building Electronics, the modern name of the auxiliary electrical systems, has thus evolved which includes systems that use electrical power to generate, process, store, or transmit information around a building. Because of the evolution of this new field, a teaching module called 'Building Electronics' has been introduced into an existing Building Services (BS) engineering course in the City University of Hong Kong. This module involves many electronic-related materials ranging from simple analog circuit design to sophisticated microprocessors. However, the students of the BS course had relatively weak backgrounds in electronics and found the module very difficult, especially in the area of microcontrollers (MCU). They complained about having to memorize complicated technical terms and definitions [2–3].

After reviewing their feedback questionnaires, we decided to employ problem-based learning (PBL) on this module. A group project was introduced for students to learn about microcontrollers. The students were required to design a circuit using MCU to perform the function of a scientific calculator. It was a good opportunity for them to acquire practical skills and their overall understanding of microcontrollers could be evaluated.

Moreover, the project consisted of several parts, requiring students to be systematic and to cooperate, otherwise the final product would not function properly. The success of the project did not only rely on the proper functioning of each part but also depended on good coordination of all the parts. The students completed each part one at a time. Initially, they claimed they lacked confidence, but, although we had expected that we would have to offer a significant amount of assistance with technical advice, this was not the case. With their own efforts and a positive team spirit, the project was successfully completed with limited technical guidance from us. The following sections briefly describe the principle of PBL and the content of the group project.

PROBLEM-BASED LEARNING

Problem-based learning (PBL) covers any learning environment in which the problem drives the learning. This means that, before students acquire knowledge, they are given a problem. The problem is posed so that the students discover that they need to learn something new before they can solve the problem. In PBL environments, students act as professionals and confront problems as they actually occur—with fuzzy edges, insufficient information, and a need to determine the best solution possible by a given date. Some examples of problem-based learning environments include research projects and engineering design projects that are

* Accepted 5 May 2003.

more than just a synthesis of previously learned knowledge.

Problem-based learning thus has several distinct characteristics that may be identified and utilized in designing such a curriculum. These are [4–6]:

- Reliance on problems to drive the curriculum—the problems do not test skills; they assist in development of the skills themselves.
- The problems are authentically ill-structured—there is not meant to be one solution and, as new information is gathered in a reiterative process, perception of the problem, and thus the solution, changes.
- Students solve the problems—teachers are coaches and facilitators.
- Students are only given guidelines for how to approach problems—there is no one formula for student approaches to the problem.
- Authentic, performance-based assessment—this is a seamless part and end of the instruction.

Posing a problem before learning tends to motivate students, as they can understand why they are learning the new knowledge. Learning in the context of the need to solve a problem also tends to store the knowledge in memory patterns that facilitate later recall for solving problems. In the 1960s, the McMaster Medical School introduced a learning environment that was a combination of small-group, cooperative, self-directed, interdependent, self-assessed problem-based learning, since when the approach has been known as 'PBL'. Small-group, self-directed, self-assessed PBL is a use of problem-based learning which embodies most of the principles that are known to improve learning. This learning environment is active, cooperative, and self-assessed and provides prompt feedback, allows a better opportunity to take account of personal learning preferences and is highly effective. Using this approach requires that teachers change. This change, in particular, expects teachers to change their role from being the center of attention and the source of all knowledge to being the coach and facilitator of the acquisition of that knowledge. Thus learning becomes student-centered, not teacher-centered.

In the PBL curriculum, it is possible to note three distinct phases of operation by students. Whether gathering knowledge through a variety of sources on the Internet, through print sources, or by speaking with experts, these stages (set out below) are characteristic of PBL.

Stage 1: encountering and defining the problem

Students are confronted with a real-world scenario through seemingly authentic correspondence. They may ask some basic questions such as:

- What do I know already about this problem or question?
- What do I need to know to effectively address this problem or question?
- What resources can I access to determine a proposed solution or hypothesis?
- At this point, a very focused problem statement is needed, although this will be altered as new information is accessed and understood.

Stage 2: accessing, evaluating and utilizing information

Once they have clearly defined the problem, students may access print, human, or electronic information resources. In the case of a city plan, calls to human resources such as the town manager or staff engineers may be of use. The Internet can be a focal point of research when a problem is constructed with that purpose. In the case of the sample problem, students may find a rich diversity of perspectives and resources preparatory to

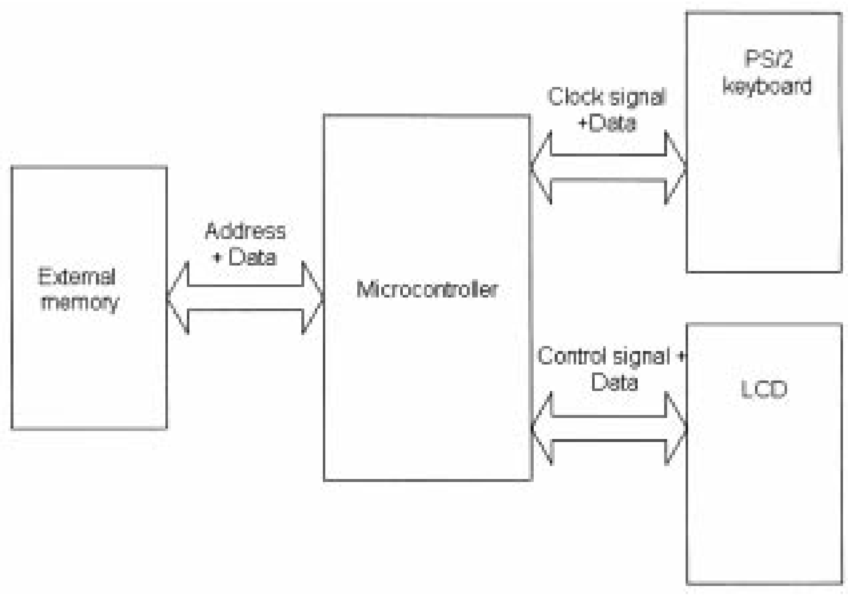

Fig. 1. Hardware design for the group project.

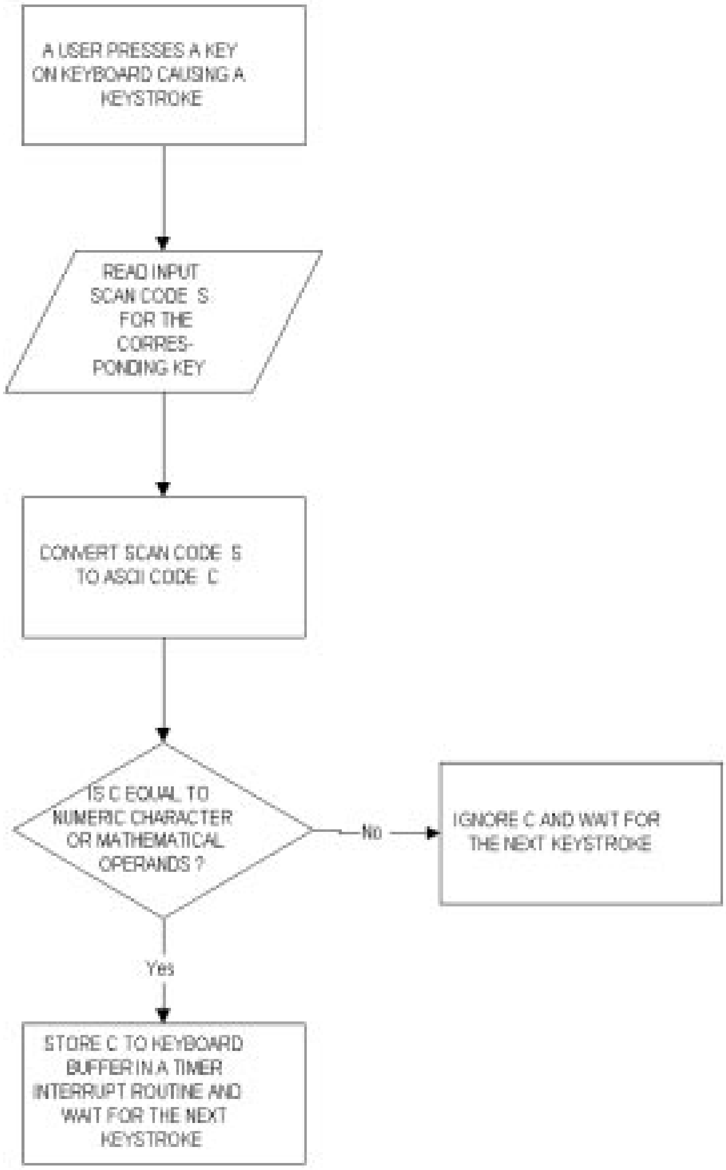

Fig. 2. The main function of the keyboard software driver.

stage 3. When utilizing the information, students must take care to appraise the value of the sources they have accessed.

Stage 3: synthesis and performance

In this stage, students construct a solution to the problem. They may create a multi-media production, a presentation, or a more traditional written paper focused around an essential question. In all cases, the students must re-organize the information in a new way.

A CREATIVE GROUP PROJECT UTILIZING THE CONCEPT OF PBL

Because of the advantages of problem-based learning mentioned in Delisie [7] and Savin-Baden [8], we employed this technique in our 'Building Electronics' module by assigning a creative group project to the class. The project itself required each team to design a scientific calculator using MCU and consisted of four main parts. As there were 20 students, five teams were formed each having four members. This guaranteed that all team members had to take responsibility for one part of the project. Two major design criteria were specified in the project: the calculator should be able to perform mathematical calculations based on the conventional sequence of mathematical operands and an error-checking capability on user input should also be included. Some materials were given to the students. These included the relevant technical information and the proposed working schedule of the four main parts of the project, namely hardware design, keyboard interface, display interface and the mathematical execution algorithm. A one-hour lecture was used to present these materials.

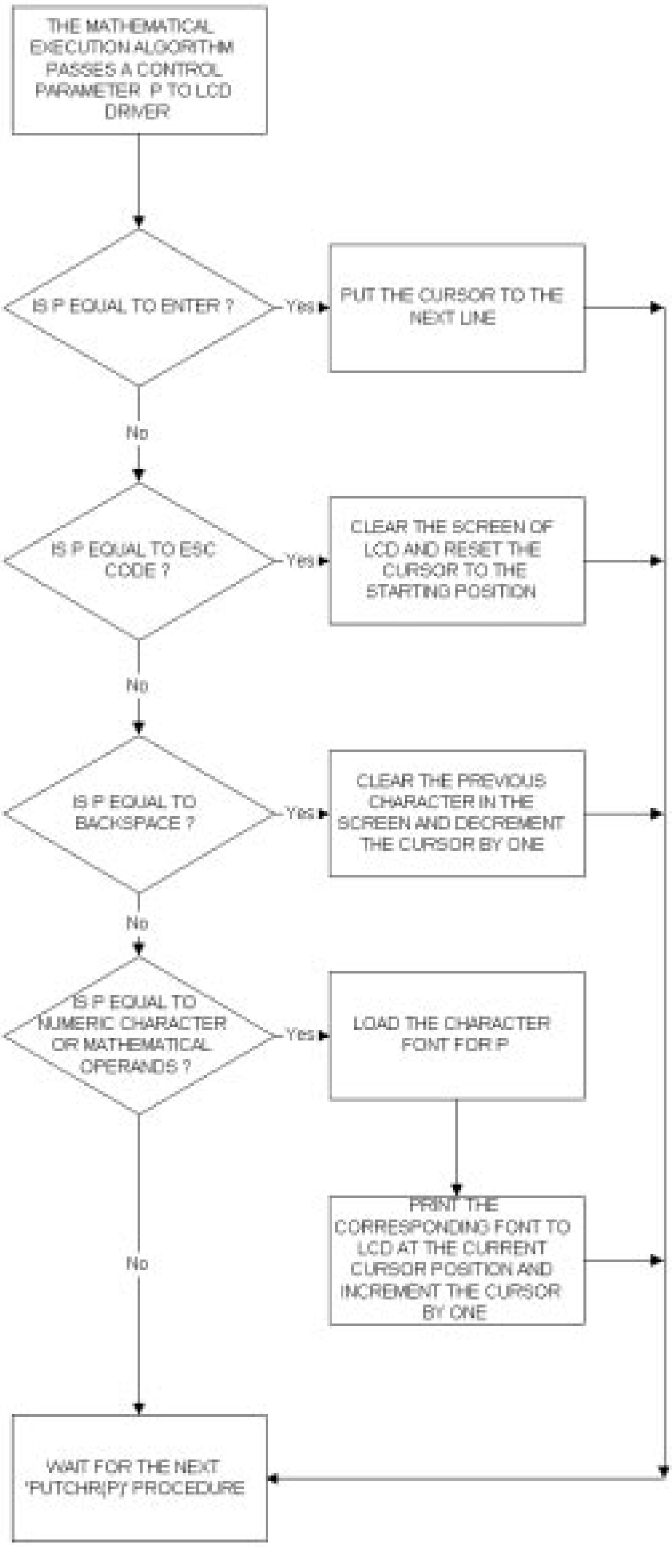

Fig. 3. The main function of the LCD software driver.

The first part of the project dealt with all the hardware components and their interfaces. A block diagram of the hardware design is shown in Fig. 1. The components included an MCU, external memory, a keyboard and a liquid crystal display (LCD). The design was crucial to the whole project, as it greatly affected later developments. Three weeks were recommended for this part.

Once the hardware design has been confirmed, the software drivers of the peripheral devices should be developed. Two drivers were required, for the keyboard and the LCD. They should

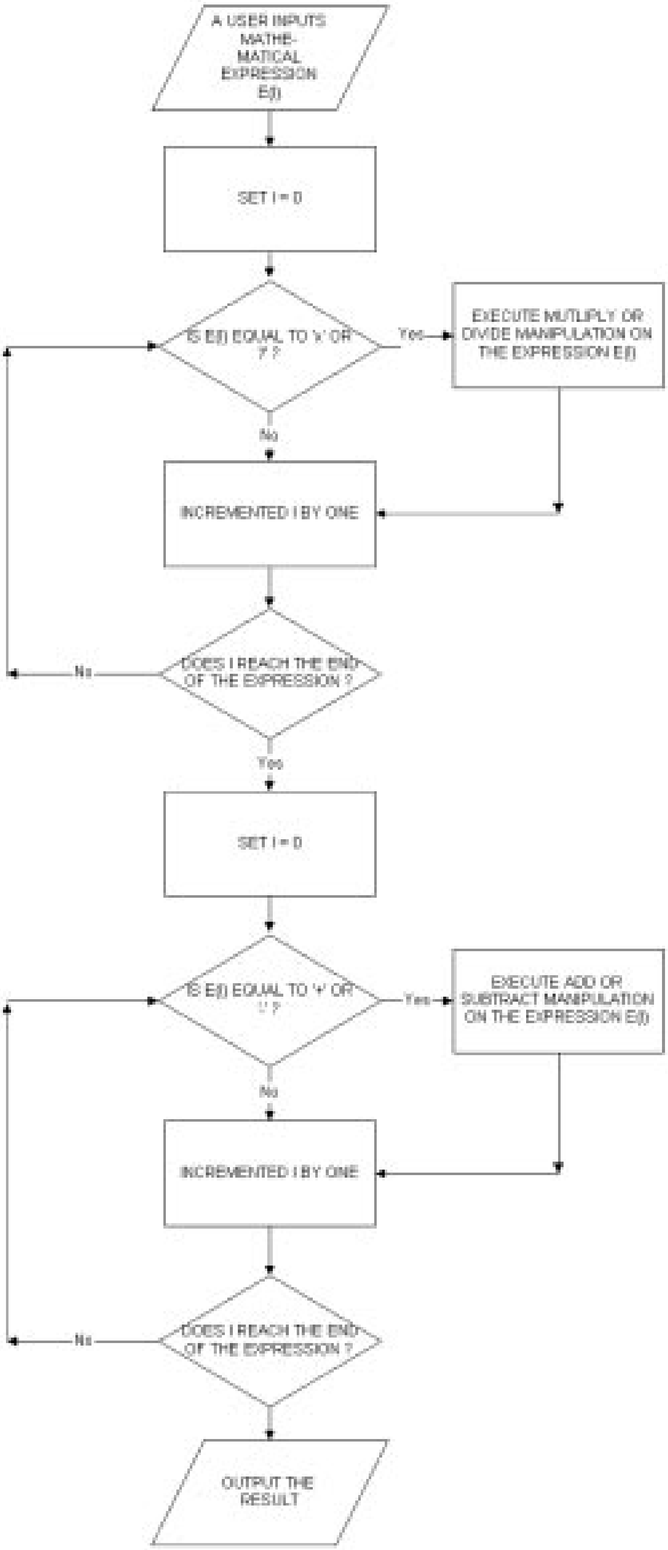

Fig. 4. The main function of the mathematical execution algorithm.

provide a good interface for the hardware so as to facilitate the final integration of work. Figs 2 and 3 illustrate the main function of the software driver of the keyboard and the LCD respectively. Each team member had to work on a driver for three weeks.

The mathematical execution algorithm was developed in parallel with the software driver development. Fig. 4 gives a basic idea of how to execute the mathematical manipulation in the correct sequence. Checking on user input is important to ensure proper execution. An error

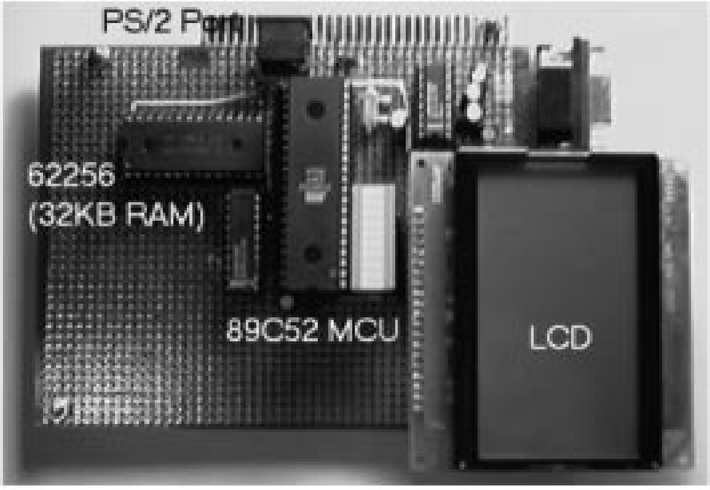

Fig. 5. Calculator designed by one of the teams.

message should be shown for incorrect user input. The same time that is spent on developing the hardware drivers should be spent on this part of the project.

The final step of the project was to make the individual hardware and software modules work together to perform as a calculator. Usually, some interface problems will need to be solved and one week is allocated for this, leaving one week for report writing. The whole project should be completed within two months.

Five areas were assessed when evaluating the quality of the project. The first focused on the functionality of the designed calculator. To meet the specifications, each team member had to resolve his/her own problems by learning new knowledge and cooperating with each other. A team achieving the basic requirements as stated in the specifications would receive 50 points. Next, the hardware design was considered and a maximum of 10 points could be scored for an optimal design. Greater utilization of hardware resources usually yielded a higher mark. The interface between the three software modules also gained marks. In fact, a team with a good interface design would find the integration work easy. A maximum of 10 points could be scored for this. Another 10 points could be earned for presentation, which could be assessed from students' reports. An extra 20 points could be allocated to a team for creativity, such as a built-in programming capability developed in the calculator.

CONCLUSIONS

At the end of two months, all teams were able to complete the group project. Throughout the project, they used self-learning techniques to tackle a problem. They collected information by themselves, carried out analysis of a problem and proposed a solution to resolve it. The teachers acted as coaches, providing technical advice, and the students had to strive to do the work themselves. More importantly, all the parts of the project were required to integrate to form an ultimate solution. Thus, a very good environment for cooperative learning was created in which they learned the importance of teamwork to achieve success. Through the discussion within a team, all team members had the chance to learn new things from each other, thus enhancing their learning capabilities.

Figure 5 shows the calculator designed by one of the teams. The team developed a good strategy to handle the project. It employed a typical PS/2 keyboard for user interface. Instead of constructing an array of keypads, the team developed the interface with the existing keyboard, which was much simpler from the hardware point of view. In this way, the team gained more time to develop the software modules, especially the execution algorithm. Thus, the project was very creative, as considerable flexibility was allowed to students to tackle it in their own way.

From the outcome of this project, we concluded that PBL was very effective in conveying technical knowledge. Students had a good opportunity to practice self-learning techniques that would be important in their future careers. Also, their learning capabilities would be further enhanced by learning to work in a cooperative environment. This paper demonstrates how we employed PBL in our course. Any readers are welcome to employ our approach in other curricula to create a more effective learning environment.

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