

Learning automation by doing it – a case-study

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Abstract - This paper presents the trends in automation teaching based on the “learning by doing” paradigm. A new experience in a compulsory curricular unit for an engineering degree is described. Several project works, based on real world environments, were proposed and developed. The group of students involved has no previous knowledge on automation theoretical aspects. They were encouraged to profound their basic knowledge by, autonomously, reflecting on their observations of real experiments. The teacher role was of a catalyst, being the learning progress built by the students themselves. The students’ feedback was very positive and rewarding. They react quite well finding no difficulty in applying automation concepts before settling all the theoretical background. The successful results were not only in the learning progress on the automation field but also on the development of their creativity, encouraging them in their future decisions and promoting synergies in team work.

Index Terms – Automation Kits, Learning by doing.

INTRODUCTION

For Socrates, the first Greek philosopher, the students are prompted to think independently by inquiring - the dialectic method. This value has arrived up to our days. But, for Plato, Socrates’ student, all knowledge is natural at birth and is perfectible by experiential learning during growth. Aristotle, a student of Plato, on the contrary, believed that thinking and sensing experience are the means to gain knowledge [1]. The thoughts of these three philosophers have been, and still are, influencing the educational concepts in our time.

As stated by Borgnakke [2] “no matter how we twist and turn learning, we cannot avoid doing”. However, we can define different and new strategies in order to give directions and organize the student process of learning.

The challenges brought on by new teaching/learning methodologies offer an interesting field for improving students and teachers’ engagement in the knowledge acquisition process, often with web-based learning environments help. These web environments can not be developed only to allow the traditional lectures and exercises support uploading. These contents are provided by the teacher for students. In this model teachers and students play a secondary role [3]; the principal actor is the web itself. So, more innovative and illustrative interactive learning environments must be developed. In the model centered in the student, the main actor in the learning process is the

student and the limelight is in the learning process. The teacher must be aware and be prepared for using virtual environments as a complement to the traditional face-to-face lectures.

Each student has his own way of learning: some learn by reading, others by listening and others by experiencing, by doing. Learning environments must include the elements to satisfy each student. Regarding automation education, it is possible to use different technologies and learning environments, in order to develop illustrative and interactive situations, as for example, virtual processes, local and remote laboratories and interactive animations. Students can develop web-animation for an automation topic; students can design a particular experimental-rig for local and remote control; students can practice topics related to automation subject using web-based learning environments, previously constructed by other students; students can solve exercises with actual equipments that others have designed and implemented. In all, this is a dynamic learning task: students actively participate in the development of the learning content and other students simply use and test them. It is regarded as a team work function. Companies are internationally networking and dividing their production and product development to several continents, international teams and the web-based document management and web-meeting systems they use are becoming more and more ordinary in everyday use. One should grow into this world already during studies [4].

In this paper, it is described an educational experience in Automation subject. A group of three students, from the 4th year of an Engineering course, design and implement a set of didactic Kits based on real environments, having no previous knowledge on automation theoretical aspects. They implement three different Kits: a crossroad traffic light management, a “small intelligent” house and a contest queue management system. The didactics kits were developed under the Curricular Unit (C.U.) Project I. During the semester, the students have near to 10 hours of direct contact with the teachers and 126 hours of individual/team hours. The remaining 4 hours are for evaluation.

In the near future, the implemented Kits are to be used in automation lessons as real world examples: developed by students for students’ knowledge development.

THE ‘LEARNING BY DOING’ CONCEPT

‘All youngsters need the opportunity of proving themselves to themselves, and education must provide such opportunities.’
- Kurt Hahn [5].

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In children's education and when there is no real harm, parents usually teach them by letting them do things: for instance how to walk. Academic teachers can use the same methodology in their pedagogical work, applying the paradigm of 'learning by doing'. In this way, students acquire and develop their knowledge by challenging.

Learning by experience engages components from the doing and the thinking. According to Kolb [6], learning from experience has four stages placed in a cycle, as illustrated in Figure 1. The learner can enter at any point in the circle, but the stages must be followed in sequence.

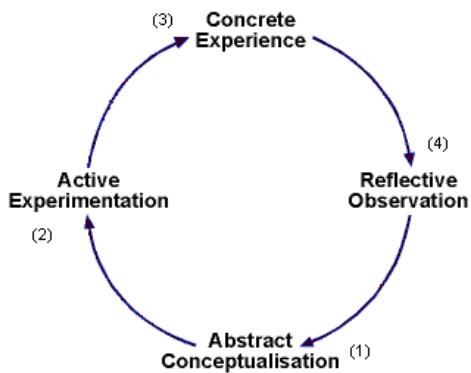


FIGURE 1.
EXPERIMENTAL LEARNING CYCLE, SOURCE FROM [6].

There is a difference between supplying information to the pupils and providing learning. To give information simply is not enough for an efficient learning. Intuition, imagination, interactivity are considered as key parts in the learning process. The learning in laboratory, where there is a strong interaction between the student and the colleagues and also with professor, is an essential tool. Here, the pupil put into practice the theoretical concepts. The pupil individually constructs, manipulates, modifies and controls the experience. This 'to learn by doing' is essential to form good professionals, in special in the different areas of engineering. Hansen [7] defends that the pupils hold back only 25% of what they hear, 45% of what they hear and see and about 70% when they apply the methodology 'to learn by doing'.

With the reorganization of the courses in the scope of Bologna, the pupils are active parts in the learning process and not mere 'viewers'. In order to raise the competitiveness, the projects considered in the curricular scope, should reflect on the resolution of problems based on situations of the real world. This motivation engaged the authors for running an experience where the paradigm 'learn by doing' was tested in the curricular unit, Automation [8].

The two academic teachers involved in the experience described, came from different scientific background and have different styles. This can be considered as a positive aspect since they can emphasize different aspects of the experiential learning cycle in the methods they use. During the semester, regular meetings with the student group were scheduled not only to give some theoretical support, but also to enrich reflection and learning in the learning process.

In the following sections a description of the experience is made.

DIDACTIC KITS

At the beginning, the teacher gave a brief overview of automation background (stage 1, Figure 1). Then, the students feel free to, autonomously, start their practical development. The experience runs successfully only with a brief guided automation overview. It obliges students to learn by reflecting on their observations of the real experiment (stage 4), encouraging them in their future decisions and promoting synergies in team work.

Three different Kits were developed: a crossroad traffic light management, a 'small intelligent' house and a contest queue management system. The first two are for future pedagogical purposes. The first is a frame toy house where students install the relevant sensors and actuators for controlling daily house functionalities: authorized front door opening, inside stair lights and alarm intrusion system. The crossroad is a home made Kit for management of the traffic lights for both cars and pedestrians. The queue management Kit was tested on a public contest ran in UM. It involved four groups from secondary and professional schools and aimed in spreading UM engineering courses. The Kit identifies registers and highlights the group answering order. All the Kits are controlled by a Programmable Logic Controller (PLC).

I. Crossroad traffic light management

In this didactic Kit the main objective was to optimize the didactic Kit (crossroad traffic lights), using the PLC as the controller system.

As illustrated in Figure 2, the main objective was to control the traffic and pedestrian lights of a crossing. As base for the control of the traffic lights, we have that the automobiles can not modify their circulation direction; they can only circulate in one direction. As to the pedestrians, they can use which ever zebra crossing they choose, as long as they activate the green button, to ask permission for crossing the road.

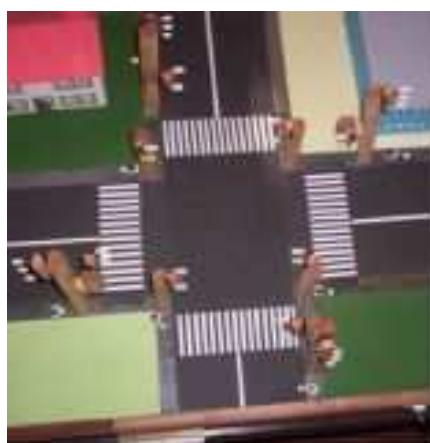


FIGURE 2.
DIDACTIC KIT - CROSSROAD TRAFFIC LIGHTS.

In order to facilitate the linking between the PLC and the mock-up, a board was designed, containing various links and connections of the traffic lights and the buttons (that control the pedestrian crossing).

The PLC used for the accomplishment of this project was an OMRON model (CQMIH with CPU 61) that has 16 inputs and 16 outputs [9]. The programming of the PLC is done by computer using the software CX-Programmer. The linking of the PLC to the computer is established by using a RS232 communication protocol.

Figure 3 represents the Grafcet for controlling the crossroad. The sequence is initiated with all the traffic lights being red (stage X1). At the same time, a timer is activated (timer0), which permits the programme to pass on to the following state as soon as it finishes counting. In the following state (X2), the traffic lights of the motorists (S1) remain red while the traffic lights of the pedestrians (SP1) changes to green (E).

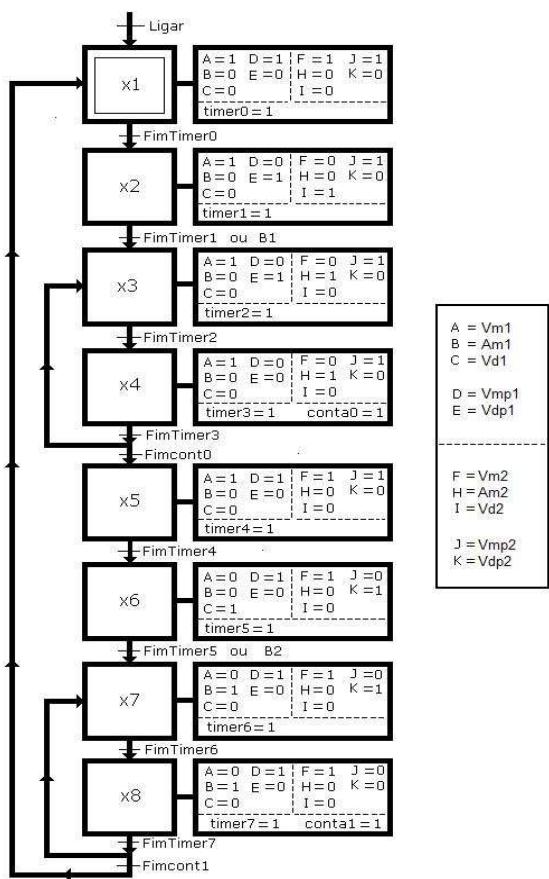


FIGURE 3.
GRAFCET FOR CONTROLLING THE CROSSROAD.

As far as the other traffic lights are concerned, the lights of the pedestrians (SP2) remains red while the lights of the motorists (S2) changes to green (I). The programme passes to the next state (X3), only at the end of timer (timer 1) or if the button (B1) is pressed. At this state, it maintains itself exactly the same as the previous state except for the traffic lights of the motorists (S2) that changes to yellow (H),

activating the timer (timer2). As soon as this state has finished, the following state (X4) is activated, thus activating the counter (conta0). Once the referred counter is activated the states X3 and X4 are activated in an alternating mode until the counter has terminated. This sequence activates, as for the pedestrian traffic lights, an intermittent green light. As soon as the counter has finished its cycle, the state (X5) is reactivated; therefore all lights are changed back to red. Once the timer (timer4) has terminated, the state X6 is activated in which the traffic lights of the motorists (S1) changes to green while the pedestrians light (SP1) remains the same. On the other hand, in consequence of the referred action, the pedestrians' traffic lights (sp2) change to green (K), while the motorists lights (S2) remains the same. To pass to the following state there are too possible options: pressing the button (B2) or the timer (timer5) finishes its cycle. On the following state (state 7) the motorist's traffic lights (S1) change to yellow while, the pedestrians' lights maintain the same state.

The sequence of all the following states remains exactly the same as the one described previously until the sequence is interrupted (deactivated) by using the Start button ("Ligar" variable, in Figure 3).

II. The "small intelligent" house

In this didactic Kit the main objective was to reactivate and to optimize the didactic Kit "intelligent house", using the PLC as control system. The optimization and improvement focus certain aspects such as:

- Organization of the mock-up featuring certain aspects such as linking of wires, adding a Vero board, module of operation, interactive aspects, among others;
- Addition of new components improving certain interactive aspects of the Kit;
- Development of printed circuits for hardware, improving the performance of the interaction between the hardware and the user;
- Elaboration of an optimized Grafcet (being this one faster and more compact, thus resulting in a better performance).

Several features were developed: staircase illumination, alarm intrusion, automatic internal illumination and entrance door opening control (Figure 4).

The staircase illumination is done by three push buttons placed as follows: one at the top of the staircase, the second at the middle (half way) and the third at the bottom. These push buttons could be replaced by using infra-red sensors, performing the same electrical functions.

If the alarm is switched on there is a light and sound signal whenever the alarm detects an intrusion. The control function activates and deactivates the alarm. The sonorous sound is performed using an independent circuit.

To control the internal illumination, a motion detector (sensor) was used, that whenever it detects movement, a signal is sent to the PLC, therefore activating the light bulb (light on).

Although there is only one motor used to open and close the door, and the PLC works with 24V to control the door,

the aid of extra hardware was necessary to perform both door actions. The door has a motor that is located underneath and a light bulb that is activated (on) as soon as the door is opened or while the door is maintained open. The bobbins permit that the door maintains itself opened or closed.

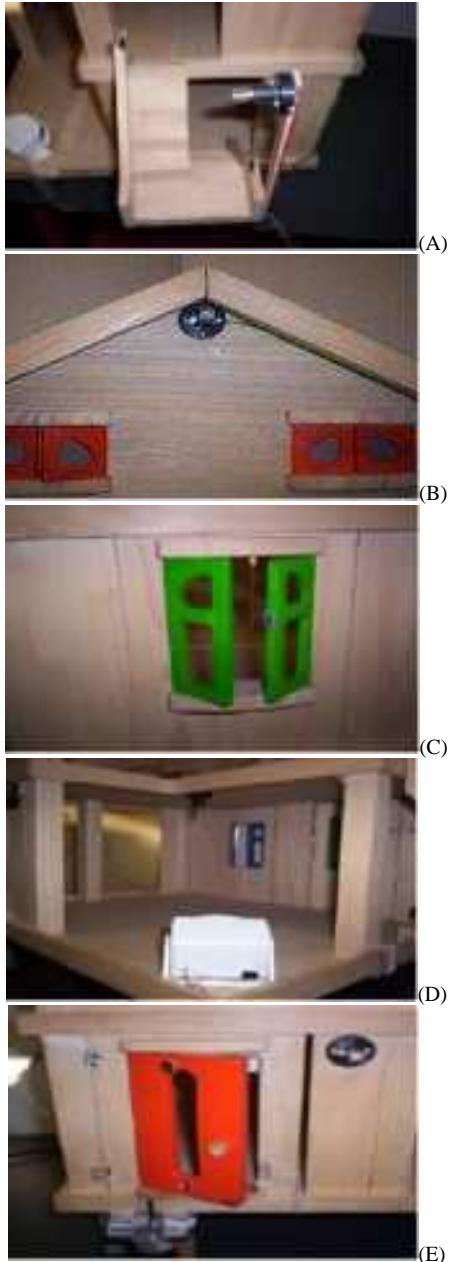


FIGURE 4.
CONTROL POINTS: (A) STAIRS LIGHT; (B) ALARM LIGHT SIGNAL;
(C) WINDOW INTRUSION ALARM SYSTEM; (D) SENSOR
MOVEMENT; (E) ENTRANCE DOOR.

To control the door, the alarm, the internal illumination and the staircase illumination it was necessary to develop new hardware. This new hardware includes various components such as relays that permit the motor to invert its rotating direction. To control the alarm circuit a well known component (the 555) was used, thus controlling the pulse every one second obtaining a similar sound as a real alarm,

(the light bulb enters an intermittent state). The sound generated is obtained by using a Buzzer.

To control the light bulb of the internal illumination a motion detector (sensor) was used. In this part of the circuit a relay is used because the motion detector only operates at 9 V. The capacitor and the relay are placed in parallel thus eliminating the existent "noise" at the end of the detector.

To illuminate the staircase, push buttons were used and a light bulb.

After studying the complete hardware to activate the Kit, a printed circuit board was built, in which was placed all of the necessary electronic components to activate the various stages of the project.

III. Contest queue management system

This project was developed as a control system for a contest queue management system, used in a public competition held at the University of Minho (Figure 5) [10]. This public competition, having as its main objective the promotion of the School of Engineering, involved four groups of pupils of different schools, from secondary to professional.

The Kit identifies, registers and enhances the reply order to be given by each group. The control selection is done by using a PLC.



FIGURE 5.
CONTEST QUEUE MANAGEMENT SYSTEM: (A) BUTTON AND
SIGNAL ORDER DISPLAY; (B) AT THE CONTEST "ENGINEERING
AND TECHNOLOGY: WHO DOES WHAT?"*

The function of the Kit is to organize the selection (order) of the reply from the groups. This order is obtained through the PLC. The system works as follows: the device possesses a pressure button and a display of four numbers, both hardwired to the PLC.

* <http://www.eng.uminho.pt/fotossemana06.aspx>

Once the button has been pressed, a signal is sent to the PLC, which processes the signal in which order it was obtained, sending to the display the respective position (from 1 to 4) indicating in what order each group is going to reply the question given.

Figure 6 shows the Grafcet that controls the contest Kit. For this Kit four buttons of pressure as well as four sets of four light bulbs have been used. Each button has to light one of the light bulbs belonging to one of the sets.

The system works as follows: if one of the buttons is pressed then only one of the light bulbs (of the group of 4), where it belongs, is lighted (activated “on”).

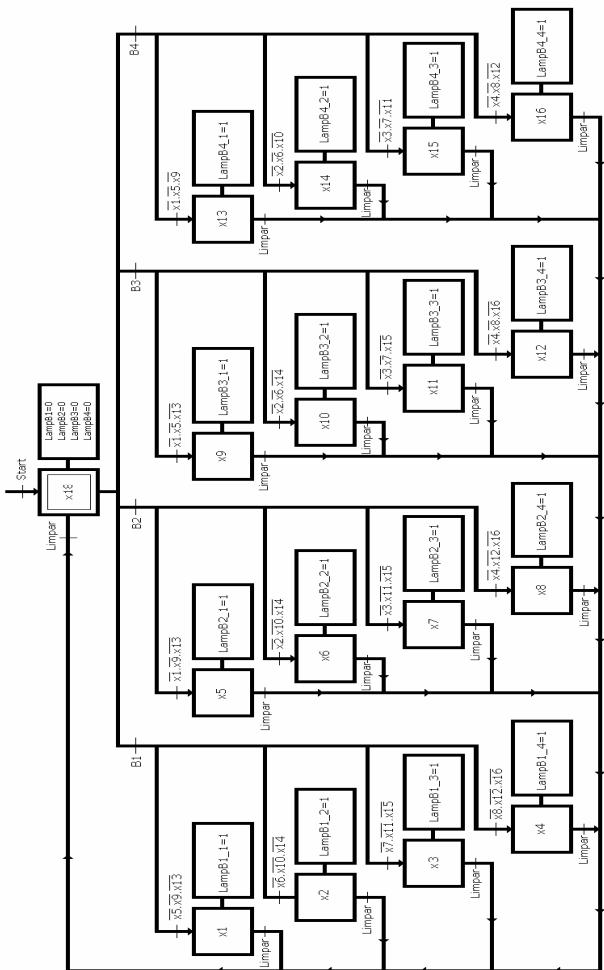


FIGURE 6.

GRAFCET FOR THE CONTEST QUEUE MANAGEMENT SYSTEM

For example, if B1 is pressed in first place this activates state X1, therefore activating the light bulb ‘LampB1_1’ (light on). In consequence of the state X1 being activated the following states X2, X3, X4, X5, X9 and X13 are never activated. If another button is pressured instead of B1 the sequence is exactly the same as the one referred before, as consequence the first light bulb of the each group is activated. If another button is pressured, for example B2, the light bulb ‘LampB2_1’ is not activated since the state X1 finds itself activated. Following the logic previously

explained, the only state that can be activated is the state X6, consequently activating the light bulb ‘LampB2_2’, therefore the following states X7, X8, X10 and X14 are never activated.

If instead of the B2 another button is pressed, for example B3, the procedure would be exactly the same, this is, ‘LampB3_2’ will be activated (light bulb “on”) therefore the following states X11, X12, X6 and X14 will never be activated, thus activating the second light bulb.

Pressuring the third button, as for example B3, the light bulb ‘LampB3_3’ will be activated (light bulb “on”), since the following light bulbs are already activated (on) ‘LampB1_1’ and ‘LampB2_2’, thus the states X12 and X15 can not be active.

Once activated the 1st, 2nd and 3rd light bulbs, when pressuring the B4 in last place, this will activate light bulb ‘LampB4_4’; in other words the state X16 will be activated since it is the only state remaining because all of the other (states) are deactivated.

FINAL COMMENTS AND ON-GOING WORK

It is the authors' belief that the paradigm “Learning by doing” fortifies the theoretical subjects presented in class. In this way, students enlarge their knowledge on the particular subject they are studying as well as they develop their creativity, their planning capacity and the communication between the working groups. Nevertheless, in the methodology based on experiential learning the responsibility of learning must not be discarded. The experiential learning cycle imposes a powerful structure of its own, like: timetables deadlines, meetings, running and final reports.

In this paper, it was described an educational experience in Automation subject. A group of three students, from the 4th year of an Engineering course, designed and implemented a set of didactic Kits based on real environments, having no previous knowledge on automation theoretical aspects. This students voluntarily accepted this challenge, being more involved, more committed, more openness and with more responsibility in their Automation learning process. They implement three different Kits: a crossroad traffic light management, a “small intelligent” house and a contest queue management system.

It must be pointed out that the Kit for the contest was not initially defined as an objective. It was a later demand by the Courses Council of the School to be running in the Contest “Engineering and Technology: Who does what”, taking place on October last year.

As far as hardware, for the crossroad mock-up, and software (programming the PLC) are concerned, the objectives that were initially proposed were achieved. All electrical connections of the mock-up were checked and verified; to facilitate the interconnection between the mock-up and the PLC a connection board was introduced. The PLC programming was done considering that the automobiles could only circulate without changing direction. The functioning of the traffic lights was optimized following the same procedure that we see in our daily base. Furthermore,

for pedestrians' safety precautions a sequence of intermittent green lights are switched on, giving the pedestrian the indication that the red signal is due to be activated shortly. The perspective used for this project could have been different, in other words the automobiles could be allowed to change direction. This new assumption would change the project in many aspects; there would have to be introduced new elements in the mock-up, such as new traffic lights and new road signals. But this is a challenge that we are keen on taking in a near future.

As for the 'intelligent house', all the functionalities previously designed were successfully implemented. In the near future, a remote control function is to be performed.

Regarding the development of the contest Kit, it gave the group a bigger challenge and more liberty to implant their ideas as far as software and hardware were concerned. The group simulated and tested successfully all of the possible situations. The feedback from the teachers, spectators and students that participated in the contest organized by the university was extremely positive. The game provided moments of true emotion and enthusiasm. In other words, the Kit and contest were a success in all aspects. As future applications of the Kit, it can be optimized and updated with more modules that can improve its interaction with the contestants and spectators.

The students had no previous knowledge on Automation theoretical aspects. Only on the following semester the students attended the Automation Curricula classes. Nevertheless, a brief introduction of the problem, performed by the teacher, at the beginning of the Project, was enough for the fulfilment of the proposed objectives. The students voluntarily accepted this challenge, being more involved, more openness and with more responsibility in their Automation learning process.

In the practical project evaluation, the students fulfilled all the initial requests. Regarding the deep theoretical

knowledge, they will be evaluated in the following semester in Automation C.U.. However, it is the teachers believe that these students performance will be very positive.

All the developed Kits can be used by other students as a demonstrative tool in Automation classes.

This project was successfully made and developed by the students. The learning by experience engages components from the doing and the thinking.

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