SHAPING THE MECHATRONICS COURSES FOR THE CONTROL CURRICULUM

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Abstract: Five years of field practice in developing and delivering Mechatronics courses in the context of a Control education curriculum, have shaped the didactic approaches in place and delivered a number concrete results from hands-on experience. The paper reports on some of the main outcomes of this undertaking, presented within an integrating framework that brings together curriculum content, didactic methods, teaching tools and organizational aspects.

Keywords: control education, microprocessor, education, mechatronics

1. INTRODUCTION

Mechatronics is a young discipline, but it has attracted early on the interest of engineering education. The educational practice of Mechatronics has been fairly developed in a variety of contexts and forms. This, in turn, has led to the identification of several important issues relating to the Mechatronics curriculum and to the didactic benefits expected thereof.

Earlier work, for instance, focused on the "integration" aspect of Mechatronics. Practitioners of engineering education pointed out that this essential feature of the Mechatronics agenda was *per se* a key didactic objective for any engineering curriculum (Alptekin, and Freeman, 1996; Amerongen, and Jongkind; Brussel, 1996).

Furthering on this concept, numerous theoretical and field studies have corroborated the value of Mechatronics in the context of an interdisciplinary engineering curriculum (Arkin, et al., 1997; Auslander, 1991; Brown, and Brown 2002; Carryer, 1995; Geddam, 2003; Giurgiutiu, et al. 2002; Sadaune, and Philippe, 2002). Particular attention has been given to the contribution of Mechatronics courses to the accomplishment of the mechanical engineering syllabus (Hsu, and Wang, 1999; McNeill, and Helm, 1995) and also to the value of Mechatronics as a stand-alone, crossbreed engineering degree (Johnson, 2000; Lyshevski, 2002; Parkin, 2002; Ume, and Timmerman, 1994) both at the graduate and at the post-graduate level.

In the area of didactic methods, Mechatronics education was proven especially receptive for the application of project-oriented and problem-based approaches (Andersen, et al. 2003; Carryer, 2002; Fraser, et al., 1993: Gardner, 2002; Hanson, 1994; Hargrove, 2002; Parkin, and Jackson, 2004; Piguet, et al., 2002; Vodovozov, 1995). This gives to mechatronics considerable appeal, as a general-purpose educational instrument for delivering generic skills and competences.

According to its classical definition, Mechatronics stands at the intersection of mechanics, electronics, computer and control. However a rather limited number of works have examined the particular contribution of Mechatronics courses to the teaching of control engineering, in contrast to the other constituent disciplines of Mechatronics, (Amerongen, 2000; Craig, and Stolfi, 2002).

Although this educational synergy is an established fact, in view of the broader extensive earlier work mentioned above, the specifics of the implementation of Mechatronics courses within a control engineering curriculum need to be investigated. The aim of this investigation is to achieve maximum efficiency and effectiveness, by providing systematic ways to design, implement and assess the Mechatronics modules within the objectives of the control syllabus.

The present work reports on some early findings in this direction, based on the educational practice at the Department of Automation of the Technological Institute of Piraeus. The Department delivers an Automation degree after seven semesters of taught courses and one semester of industrial practice. Two Mechatronics courses were introduced in 1998, in the context of a programme to advance and modernize the curriculum. The courses were initially termed Mechatronics I and Mechatronics II and were taught in the fifth and sixth semester, respectively. Following a review of the curriculum, these were replaced by two new courses (Mechatronics and Applications of Mechatronics) and shifted one semester downstream in the Automation programme.

The team responsible for the delivery of the modules, developed an initial solution for the courses, adapted to the requirements of the Automation curriculum, on one hand, and in line with the methods used and reported internationally, on the other. This focus led the team to seek answers to a number of key issues. On the top of this list was the fact that several topics of a conventional Mechatronics programme were covered by other parts of the Control education curriculum of the Department of Automation. This is particularly true for basic technological subjects like electronics, electrical circuits, control systems, microprocessors etc. covered in specialized courses. At the same time, it was realized that few existing control or technology courses developed the problem-solving abilities of students. Also, none of these courses introduced the aspect of the integration of different technologies nor to offered systematic approaches to deal with the real-life, crossbreed integrated devices and systems.

These requirements were examined in relation to internationally reported practice and the philosophy underpinning the development of Mechatronics curricula for different disciplines and audiences. In line with these approaches, the Mechatronics courses were developed with the primary objective to foster the capability of Automation graduates to organize and resolve technological problems, and to integrate in multi-disciplinary teams with specialists and other technologists.

Over the last five years, the Laboratory developed also a participatory style to the way Mechatronics is taught. Students must develop their own problem-solving approaches to the Mechatronics problem given to them. These approaches should be linked to and based upon the individual experience of each student. In this way, the Mechatronics modules are considered not only as conventional courses but also parts of a support environment for the individual development of students; the modules create the "boundary conditions" required to keep the student's own personal learning on track. Five years of teaching practice shaped these general objectives into a concrete learning process, aspects of which are reported here.

2. MODEL OF THE LEARNING PROCESS AND SPECIFICATION OF REQUIREMENTS

An essential goal of the Mechatronics courses is to foster the active and motivated participation of students. The interest of students was found to relate to a number of factors, including challenge, competition, group participation and more. These findings were largely in line with the mechanisms at play reported in earlier educational analyses of the Mechatronics curriculum, as for example in (Alptekin, and Freeman, 1996; Auslander, 1991).

The search for a structured way to represent these factors and their interplay led to the development of a theoretical model for the learning process of the student. The model comprises four stages as shown in Fig. 1.

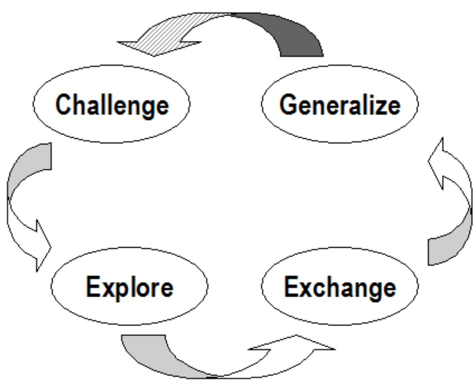

Fig. 1. The four stages of the "students' loop", according to the model of the learning process

- Challenge. The student is presented with a problem statement that includes a complex (though not necessarily practical) goal. The goal 'feels' generally feasible but the way to achieve it not straightforward.
- Explore. The student develops an individual approach to resolving the problem, including breaking down the problem in manageable parts and deciding which parts of the solution are 'outsourced' and to whom.
- Exchange. The student exchanges views and solutions with others: fellow students, peers, teaching staff. Also, the student manages the distribution of work with partners.
- Generalize. The student is led to solidify selected parts of the inputs he has absorbed into a small number of reusable, therefore general, pieces of learning.

The results of the last stage, generalization, are useful for reviewing the problem under a new scope or for tackling another problem: e.g. working on the next assignment. Therefore, this stage feeds into the first stage of the process, thus forming a continuous loop, as shown in Fig. 1. This 'student' learning loop is nested within an outer 'educator' loop, shown in Fig. 2 that includes tasks to continuously monitor, evaluate and evolve the Mechatronics courses.

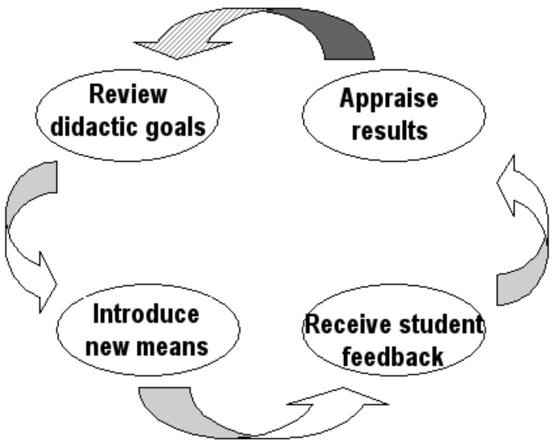

Fig. 2. The four stages of the "teachers' loop", according to the model of the learning process.

3. IMPLEMENTATION OF THE SPECIFICATIONS

Practice with the 'educator' loop mentioned in the previous section, led to a number of practical solutions regarding the content of the course and the educational tools used. Each course is designed as a series of assignments (problems) of increasing complexity. Any of these problems can be performed using the same basic equipment: a small wheeled platform. The students are asked to impart a specific behaviour or function to the robotic platform that is fully maintained by the Laboratory (Chamilothoris, and Voliotis, 2003; Gopalakrishnan, et al., 2004).

The features of the educational platform and the process of its development have been reported in (Chamilothoris, 2002; Chamilothoris, and Voliotis, 2003). The current form of the device, depicted in Fig. 3 and termed the 'Mechatron II', includes a differential wheel drive, power conditioning circuitry, a solder-less electronics board and a multi-tasking computer-on-a-chip device.

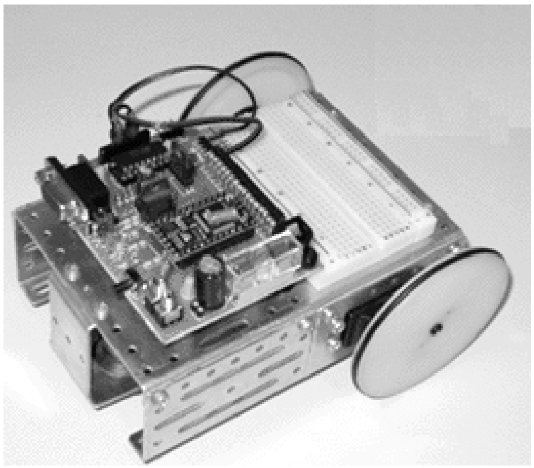

Fig. 3. The 'Mechatron II' educational platform in its basic "stripped" form, before the addition of sensors, actuators and interface circuitry.

Students have access to the equipment and the facilities of the Laboratory during normal course hours and also during 'open doors' periods, to the extent of approx. 12 hours per week. Also, student teams that reach an advanced stage of work towards developing a solution are given a 'private' Mechatron unit (Fig. 4) and accessories for exclusive use by the team up to the final examination.

Early in the semester (usually at the second or third session), students form teams of two or three members. The composition of teams remains constant during the semester. Students are encouraged to consider ways to select their team partners with the main objective to combine skills and knowledge. The final examination is organized as a game event, with teams competing against each other.

4. TEACHING PRACTICE AND INDICATIVE RESULTS

To put the educational model into practice, the courses rely on various support services and organizational structures. A key component of this support practice is TEI teaching assistants that are made available during normal course hours and also in a number of special 'events' like pre-competition test runs etc. Also, a small number of students that have successfully completed the modules act as peer facilitators, sharing their experience with individual students and teams and helping them organize their work. These peer facilitators also staff the Laboratory during 'open doors' practice.

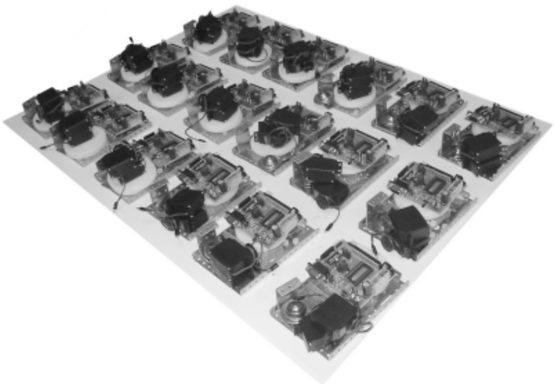

Fig. 4. "Mechatron II" platform kits distributed to student teams for preparing individual mechatronic solutions.

The content of the lectures is organized in two interrelated parts. The first part, taking roughly half of the total sessions of the semester, focuses on presenting a number of selected topics that are relevant to the specific problem assigned to students on that particular semester. A typical semester may cover the topics of control of motors, basic opto-electronics, concurrent programming and tuning of two-term controllers, for instance.

The second part of the lectures focuses on more general engineering topics, illustrated through reference to the experience of students with the particular problem given that semester. A typical semester may include, for example, organizing the work of the team, breaking down the work in milestones and deliverables, scheduling and planning for the development of the solution, performing diagnosis and finding expert assistance, preparing reports and presentations etc.

Both course attendees and peer facilitators are strongly encouraged to provide feedback to the educators loop. Each semester, a special debriefing session is devoted to the assessment of the various parts of the modules. Depending on the results of this assessment, a number of projects are defined and run over the next semester.

Table 1. presents the relationship between these teaching practices (matrix rows) and the four stages of the learning model (matrix columns). At incidence points, a full disk indicates a major contribution and a circle indicates a secondary impact.

The incidence matrix of Table 1. is one of the key tools used by the team to map the present coverage of key topics by the teaching system. The mapping process uses a marking system to appraise the individual contribution of each teaching practice and then evaluates the overall support provided to the stages of the model. The method was also found to be useful in planning for the introduction of new methods, the adaptation of systems at place and, in general, the evolution of the courses.

Table 1. Support of the learning process

Means	*Challenge*	*Explore*	*Exchange*	*Generalize*
Problem assignments	●	○		
Evaluation through competition	●		○	
Mechatron II platform	○	●		
'Open doors' sessions		●	●	
Operation of teams		○	●	
Assistance by peers			●	○
Assistance by teaching staff			○	●
Content of lectures	○			●

The views of the students were recorded using a combination of means, including anonymous surveys with questionnaires, moderated and informal discussions, and non-technical questions introduced in the final examination papers. Table 2. summarises the responses of the students on a number of key issues relating to the didactic objectives of the mechatronics course. The figures are expressed in percent of respondents and represent aggregate values, based on nine semesters of implementation of the Mechatronics modules.

Table 2. Response of the students

Opinion on the corresponding topic (also in relation to other courses of the Control curriculum)	*Very Positive*	*Positive*	*Indifferent*	*Negative*
Communication skills and teamwork	22	55	15	8
Individual completion, self-motivation	36	45	15	4
Division of work, other non-technical skills	24	56	13	7
Self-confidence, esp. regarding "core" control engineering topics	42	32	19	7

5. CONCLUSIONS

Shaping the Mechatronics courses within the Control Engineering curriculum is a dynamic and adaptive process, with multiple feedback loops running at different speeds. This is in line with the broad range of benefits that the Mechatronics courses can bring to the control engineering education. Mechatronics helps develop in students' capabilities for teamwork, technical communication, interdisciplinary work, problem-based thinking and more. It can also help students of control engineering solidify their understanding of control and automation methods and techniques.

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