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A Hybrid Interdisciplinary Mechatronics Engineering Course Using Content Based Learning and Project Based Learning

Prof. Genisson Silva Coutinho P.E., Instituto Federal de Educação, Ciência e Tecnologia da Bahia

Genisson Silva Coutinho currently teaches in the Department of Mechanical and Materials Technology at the Instituto Federal de Educação, Ciência e Tecnologia da Bahia. He is a mechanical engineer and holds a Bachelor's degree in law and a Master's degree in mechanical engineering. He has been teaching at different levels, from the first year of technical high school to the final year of mechatronic engineering, since 1995. He also has considerable experience in the design and implementation of mechatronic and production engineering courses. His non-academic career is centered on product development and manufacturing processes.

Dr. ANA RITA QUEIROZ FERRAZ, UNIVERSIDADE ESTADUAL DE FEIRA DE SANTANA

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Mrs. Cristina Voigt Coutinho, Voigt Brasil Recursos HUmanos

Director of Voigt Brazil Recursos Humanos. Psychologist graduated from the Federal University of Santa Catarina, with postgraduate studies in Psychodrama at the Brazilian Society of Psychodrama and Organizational Psychology at the UNIFACS. Acts as a psychologist in clinical and organizational area, with 18 years of experience in managing people, developing programs for leaders and teams. She is also a senior level Coach, accredited by the International Coach Federation. As a teacher she gives classes in postgraduate courses of Personnel Management , Organizational Psychology and routines Labor. She was Director of Benchmark and Training from The Brazilian Association of Human Resources, Section Bahia.

A Hybrid Interdisciplinary Mechatronic Engineering Course Using Content-Based Learning and Project-Based Learning

Abstract: *This paper presents and discusses the implementation of a mechatronic engineering course with an interdisciplinary model using both content-based and project-based learning. The work involved a team of more than 20 teachers from different disciplines. The main skills and knowledge that a mechatronic engineer should acquire during the course were listed and then graded in terms of the projects for each semester. A series of projects were then defined which required both theoretical formulation and practical results in terms of a product or system. Gradually increasing levels of difficulty provided the essential skills and content that a conventional course would not have provided. Rather than a single tutor, all of the teachers had been asked to connect their classes with the possible demands of the projects Progress was discussed at weekly and monthly meetings. The results were excellent and several student research and competition groups were formed and went on to win national and international prizes. We present and discuss the main aspects of the implementation process, the benefits of the course, and difficulties such as the barriers raised by the faculty team, problems with infrastructure and the students themselves.*

1. Introduction

Mechatronic engineering is essentially multidisciplinary engineering. Bringing together computing, electronics, mechanics and other sciences requires an extensive course, which, without the use of active learning strategies, will leave the students with certain deficiencies, especially in relation to practical skills.

In this paper we describe our experiences in implementing a mechatronic engineering course during the period 2001-2006 and present some important results and pedagogical implications. Although this paper only describes the process of implementation until 2006, the course continues to be taught and the methodology has, with some adaptations, been adopted by several other universities in the state.

2. The Course

2.1 Initial context

For legal reasons, engineering courses in Brazil must include a minimum workload corresponding to 10 academic semesters with 4 hours of classes per day. The mechatronic engineering course described here was designed to comply with this requirement. As soon as we began to discuss curricular issues, workloads and content, we realized how difficult it was to establish sets of disciplines that would provide seamless interdisciplinarity throughout each semester. We concluded that simply using a traditional model based on compartmentalization of the knowledge in autonomous disciplines, although very common in engineering courses, would leave a big gap in the students' training, since mechatronics, perhaps more than any other industrial area, requires the intensive use of applied and integrated technologies and knowledge. A timetable including evening classes was also essential as most of the students work during the day, greatly reducing the time available for intensive study and the completion of assignments in every discipline. On the other hand, many of these students were already working in industry, using the principles of mechatronics and gaining extensive practical experience.

In 2001, there were very few mechatronic engineering courses in Brazil and all of them had characteristics which indicated how they had been designed. When a course was associated to an electronic engineering department the curriculum disciplines were predominantly from this area, complemented by other disciplines related to mechanics and computing. The same was true when the course stemmed from a mechanics department; 60% of the disciplines were from the mechanical area, and the additional ones included computing and electronics.

The fact that there was no specific curriculum pattern allowed us the flexibility necessary for a more detailed study of profiles, pedagogical features and educational models that would give students the knowledge that a mechatronic engineer needs, based on the four pillars of 21st century education: learning to learn, learning to do, learning to live together and learning to be.[1] Because of the curriculum guidelines established by the Brazilian Ministry of Education, we decided to innovate and create a hybrid model using both content-based learning and project-based learning. The curriculum was redesigned to allow the projects for each semester to be presented to students, discussed and problematized in the classroom by all of the teachers. As an example of the changes made, a specific discipline was created to focus on planning and team work, computer programming was brought forward to the first semester and physics (kinematics and dynamics) was moved to the second semester. Curriculum design was also directed towards the automotive and petrochemical industries which are part of the local economy.

2.2 The model adopted

In each semester a project was defined with specific guidelines and students were divided into teams of 10. One teacher was designated as a general advisor, although all teachers of all disciplines were to support the project by discussing issues related to their respective disciplines.

Regular classes were grouped into daily blocks of four hours with normal exams and an interdisciplinary project for the semester focused on the design and construction of a solution to a given problem. Additional assignments outside the context of the main project were discouraged.

Before the beginning of each semester, there were numerous discussions with groups of teachers to identify projects involving the majority of disciplines and each teacher suggested aspects of their discipline which could be addressed. In other words, the projects were defined in an interdisciplinary manner and only then formatted in terms of requirements and demands before being presented to students in the first week of classes.

The academic and pedagogical coordinators defined a set of projects with a view to the course as a whole, and as this was done in a very intuitive way, it was easily assimilated even by those teachers with no knowledge of mechatronics. Initially the course was designed in accordance with the general profile of mechatronic engineers and their work environment as well as the particularities of the region. On this basis, axes of knowledge were created and the necessary skills defined, while taking into account the government's curricular guidelines.

The formal disciplines provided the knowledge base and some practice, but were still dissociated from the interdisciplinary reality of mechatronics. For this reason the interdisciplinary projects had to include not only the conceptual aspects of a solution, but also its execution in concrete terms, meaning that each project should result in a device, machine or object capable of solving the problem originally submitted. This requirement would ensure the integration of knowledge, the practicalities and the holistic view so important to mechatronic engineers.

In order to guide coordinators and teachers in the definition of the projects, the following premises were stated:

a) Basic premises

- Projects should result in practical execution;
- Projects should involve all of the disciplines taught during the semester;
- Projects should have increasing levels of complexity, always adding to the previously acquired knowledge.
- In the first four semesters, projects should use scrap material and other low-cost components.
- For the remaining semesters, the university should provide components and higher value equipment such as Programmable Logic Controllers (PLC's), servo motors, drives, Computer Numerical Controls (CNCs) etc. Other items should be sought and acquired by the teams.

b) Technical premises

- The first semester project should address issues related to handling and mechanical positioning, so the use of a stepper motor, an elementary component in mechatronics, was established as a key element. Students had to build their own drivers, program the necessary communication and build a solution, for example a device to help people with physical disabilities to write or draw.

• The second semester project should address issues related to measurement and data acquisition. The key element was an angular position sensor, such as an encoder. Again, students had to design and build the equipment and measure and process the acquired data. As an example, they were given the task of developing studies of a simple pendulum (classical model), to evaluate the effect of friction and other disturbances to its motion and the results had to be presented graphically in real time.

• The third semester project should address issues related to open loop control and positioning. Here the students were challenged to use the concepts of positioning and measurement acquired from previous projects to move a particular component, so in the third semester we proposed the construction of a crane that had to collect a component in a predetermined location and move it to another position.

As we can see from these early projects, the basic idea was to build a knowledge base, starting from simple problems such as positioning with stepper motors, position measuring with an encoder and open loop control, gradually adding more advanced devices, including servomotors, programmable logic controllers, inverters, numerical controls, industrial networks and so on. Basic knowledge of programming, mathematics, physics, control and electronics, among others, were gradually introduced in an applied fashion.

For personal reasons the author responsible for the original concept had to leave the course in 2003, and the remaining team made some changes disregarding its nature. Interdisciplinary projects were still presented, but without taking the interconnections of mechatronic engineering into consideration. The necessary background to the demands of each semester was not provided, and so there was merely an interdisciplinary bias to the projects developed at this stage. Examples included a mini sailing boat and a lyophilization machine. Despite promoting teamwork, planning and construction, these new projects did not add conceptual components related to mechatronics.

In 2005 the original team resumed the project, seeking to return to the guidelines used at the beginning of the course, but in a new situation: the curriculum had been changed and a discipline named “interdisciplinary work” had been introduced. This was an attempt to insert the concept of interdisciplinarity into a disciplinary model, i.e. to frame the new epistemological approach in a traditional model. In this new context, all we could do was define projects which provided the students with the essential competencies of a mechatronic engineer, giving students at advanced stages of the course problems which encompassed the use of PLC 's, inverters, servomotors and other devices. Another change was the inclusion of final projects instead of interdisciplinary projects for the last two semesters of the course, which had the advantage of developing skills and competencies associated with individuality and the capacity for personal achievement.

2.3 The assessments

At least 30% of the grade for each subject was awarded for interdisciplinary work. In specific cases such as computer programming the weight of interdisciplinary projects was even greater. The rest of the grades were obtained through tests and other individual or group activities, maintaining the classical dynamics of classes but with the caveat that they should not overwhelm students with new assignments. Of equal importance to the device produced was the final report. It had to detail every stage of the process and present theoretical reflections about the difficulties and successes. Finally, the prototypes were presented at a technology fair, at which the students were available for questioning by teachers and guests, although the former had already received and evaluated the reports in advance to enhance the discussions on the day of the event.

3. Main difficulties

3.1 The faculty

We found that, due to their own training, there was great resistance within the faculty to the implementation of this model. This resistance consisted partly of technical objections raised mainly by teachers of core subjects such as mathematics, physics and chemistry, among others, who being unfamiliar with engineering problems were reluctant to support and integrate the projects. On the other hand, there was also behavioral resistance from those teachers already accustomed to a routine of ready-made lessons who did not want to leave their comfort zones to develop and implement new classes integrating the specificities of each project. Resistance was generally expressed passively in the form of ill will or a lack of participation, but in extreme cases there was an explicit attempt at obstruction. As an example of this, one teacher, when consulted on the design of an automated pendulum, told the students that it was all nonsense because it could easily be done with MatLab[2]. After a short meeting, the coordinators convinced the students to build the equipment and showed that there was no need for software, because the equations of the pendulum were very simple. The interesting point to emerge was that one team quickly encountered a 'serious problem': their system only worked at night. Eventually they discovered that bright daylight saturated the rotation sensor, but this case neatly demonstrated the misconception of the teacher who wanted to use MatLab: such a situation could hardly be imagined a priori. It also served to prove the old adage that "Theory in practice is a little bit different".

3.2 The students

Under the influence of the teachers, the students' first reaction was also to reject the unfamiliar methodology, arguing that it would lead to increased individual costs, as they would have to purchase the necessary components, and an increased workload due to the extra-curricular meetings needed to design and execute the projects. We were able to show that the costs would be very small as the projects would make use of scrap material and that their study time would be optimized since they could concentrate on only one project per semester instead of many other assignments.

3.3 The infrastructure

Since none of the members had any experience with similar hybrid models, there was no structure to support the amount of work going on simultaneously. Students demanded places to store, build and test their projects as well as the machines and tools essential to building them. None of this was provided for, since only the traditional laboratory facilities for demonstrations and small experiments were in place.

3.4 The other departments

As the first projects began to be implemented, coordinators of other disciplines found themselves in an uncomfortable position in the face of so much activity and excitement on the part of the mechatronics students, and reacted by standardizing lessons and content in order to derail some interdisciplinary interactions. As their courses had no concrete projects, there was no reason for teachers to devote time to themes pertinent to interdisciplinary projects.

3.5 Actions

Teacher training: Training courses and frequent meetings were held to involve teachers and instruct them in the principles of interdisciplinarity and assumptions of the course. Interaction with these teachers was essential to the dialogue among them and with students, as it demystified habits derived from the traditional education they had had and uncritically repeated. A great effort was required in such meetings, especially in the early stages of the course, but also served as a monitoring process. In these sessions teachers had the opportunity to listen to their colleagues and present questions for discussion. The main issues were related to the difficulty in reinventing their disciplines with a focus on interdisciplinary projects, abandoning the established hierarchy and sequential content. It was observed, however, that many teachers were stimulated by the enthusiasm of the students, as well as the results achieved.

Substitution of teachers: In the most critical cases it was necessary to replace the most resistant teachers with others who had the necessary motivation and involvement.

Additional infrastructure: Two workshops specifically for the development of the projects were opened at the end of the first year. These facilities included lathes, milling machines, welding machines, oscilloscopes, multimeters and other equipment essential for carrying out the projects. It is worth noting that earlier students had used their own homes as workshops, not to mention the classrooms and hallways of the institution, but despite these restrictions the projects were successfully executed.

4. Results

4.1 Technical

It proved possible to measure some of the results objectively. Attendance, for example, was better than other engineering courses at the institution. According to official university sources, the dropout rate among mechatronics students was at least 40% lower than the other engineering courses. Incoming students remained at around 150 per semester for at least 2 years, so that after only three semesters, the course had at least 400 students enrolled and attending regularly.

Subjectively, we noted the increased self-esteem of students and their satisfaction with the results. Setting up teams for robot war and sumo robots competitions and the excellent results obtained attracted attention to the institution. Our students were Brazilian robot war champions at the National Meeting of Control and Automation Students in 2005 and again in Venezuela in 2006, and two teams did very well at the RoboGames in San Francisco, USA, in 2006. In addition, the students also were invited to talk about interdisciplinarity to teachers from different courses, giving evidence of the intellectual flexibility to operate across disciplines, while breaking the rigid hierarchy of content.

Currently, former students occupy prominent positions in major local and national companies, always reporting that the theoretical and practical works developed during the course gave them the necessary skills and knowledge to achieve professional success. We have also observed a number of former students performing entrepreneurial activities in the area, including business incubators and industrial patent registrations.

4.2 Pedagogical

Some observations arising from studies and surveys conducted since the program was implemented in 2001, such as the thesis *Variações da Forma na Cena Educacional: Experimentação e Corpos (Im)possíveis* [3] , should be mentioned. These studies propose methods which differ from the generally accepted policies in Brazilian education[4] and in engineering education specifically. One of these is that the course was designed to invest in inventive learning and to recover the 'art of engineering'.

The project required the students and teachers to adopt a new cognitive attitude, due to the tension between existing knowledge and the lack of real 'know-how'. Such discrepancies demanded inventiveness in the face of problems which are not immediately susceptible to a given solution, as generally occurs on engineering courses where the results of laboratory exercises and experiments are known to teachers in advance. This practice results in the formulation of false problems which reinforce the policies of recognition and repetition, just as they ensure the validity of *a priori* frames of reference. In other words, if the problems presented seem unusual to the students, the same cannot be said for the teachers, who overvalue memorization, linearity in the presentation of disciplines and adherence to the curriculum and the timetable. In this style of ‘banking education’[5], teachers deposit knowledge which students welcome uncritically, strengthening modern science models which stress the learning of invariable scientific laws under which control and forecasting are feasible, which is at odds with the complexity and inventiveness of research and learning.

Most teachers did not have the initial curiosity necessary for investigation, but as the projects developed, the students took them away from their comfort zones by abandoning the passive role of the student in “banking education”. This confronting them with difficulties, which revealed the error of relying on the safety of answers wrongly related to the role of the teacher.

Learning began when the students were confronted with a challenge which required ingenuity in solving the problems that arose during the planning and construction of the suggested prototypes, and it was not unusual to see them thinking in an interdisciplinary fashion. This did not happen with teachers who were restricted by the limits of disciplines and curricular structure. We could say that the major objections to the project were found, to a greater or lesser degree, among teachers reluctant to face the changing directions and uncertainties typical of the ‘art of engineering’, and the disruption caused to the disciplinary boundaries.

The relationship between engineering / invention and problematization at the heart of the proposed project resonates with the ideas of Bergson[6] when he discusses ‘the creative potential of real problems’, although the work of Bergson (1999) and Deleuze (1988) was not known to the coordinators at the time. The fact remains that the intuition and imagination of the students were mainly boosted by a shortage of material for the construction of prototypes, which were largely created from recycled material. While students remained focused and curious, the lack of ‘ready materials’ created an atmosphere of enthusiasm, playfulness and solidarity between them, which became a game of inventiveness with unusual techniques and tactics.

The coordinators worked to promote dialogue between teachers starting with the formulation of the problems, and continuing through the follow up of the projects, creating new challenges to increase questioning and avoid a simplified and immediate solution. This instigation was also taken to the students who sought support and the continuous questioning forced them to replace discovery with invention. Teachers were urged to think and act, based on both substantive classroom issues and those arising from the projects themselves, with a commitment to inventive learning, the affective reactions triggered by uncertainty, a dialogical construction and interdisciplinarity itself.

A similar monitoring process was applied to the students. Their difficulties with the technical report were noticeable, which is not unusual considering that students of engineering have poor skills in writing scientific texts. However, we understand that this fact also constituted a relevant learning process and observed that each semester the quality of reporting improved.

It should be emphasized that the faculty was mostly comprised of engineers, whose training includes mainly technical issues, uninfluenced by ethical, aesthetic, political and epistemological considerations. Working with them demanded continuous monitoring in the face of resistance to reflections about education and the role of the teacher in contemporary engineering. It is fair to say, though, that their own training does not help them to conduct group work, or encourage them to invest in the collective creation of knowledge.

5. Discussion and future works

The issues raised by this study suggest that it will be necessary to review the objective of engineering generally and mechatronics specifically, as well as continually changing the job description of a mechatronic engineer due the complexity and demands of social life.

Although the mechatronics engineering course discussed in this paper began almost empirically, it presented major advances in methodological terms and points to the need for further study of numerous issues such as research into a new epistemology for engineering education, a discussion of the nature and reality of engineering and subjective questions about matters involving teachers, students and support staff.

In future studies, maybe in a doctoral study, it is intended to investigate the reactions of the students to the new proposal in more detail and the changes in perception arising from the continuity of the methodology. Another issue that deserves study is related to the various professorial visions and how they impact on the results of the methodology. Teacher education also deserves to be the object of study, since, especially in the case of engineering, they do not have an adequate background to work in interdisciplinary teaching.

Despite the fact that the authors are no longer members of the faculty, the methodology continues to be applied during the first four semesters of the course.

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