Academic synergy through integrated mechatronic projects

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***Abstract*—This Innovative to Practice Work in Progress paper presents an approach to obtain synergy by implementing an integrated mechatronic project within a postgraduate program. Mechatronics has been a reference for synergetic integration of technology. However, synergy is obtained not only from technical issues, but through professional skills. Nevertheless, traditional education and industry standards focus only on the technical side. The study case is performed within the program Integrated Design of Technical Systems by implementing strategies such as integrated scheduling, integrated assessment and project proposal with application fields such as agriculture, robotics, health and mobility. This approach does not require additional credits for a project course, since the project lies underneath the courses. It has led to an increase of enrollment of students, which is significant during times when less engineers opt for further technical education.**

***Index Terms*—mechatronic, synergy, design, technical systems**

I. Introduction

Mechatronics, since its origin in the 70's, has promoted the synergy of technologies leading into products that offer more attributes. Different industry standards in fact define mechatronics as the "synergetic integration of mechanical engineering with electronic and intelligent computer control in the design and manufacturing of industrial products and processess" [1]. And synergy, by definition, is the combined power of a group of things when they are working together that is greater than the total power achieved by each working separately[1].

However, bringing mechatronics into practice is not an easy task for either (i) teaching, (ii) learning and / or (iii) implementing, and so is its synergy promise. Knowledge rapidly grows and changes every day, and the only way to deal with it seems to be through teamwork, one of the professional skills lacking in education of many undergraduates according to [2]. Unfortunately, traditional education and industry standards usually focus mainly on technical skills. In fact many mechatronics undergraduate and graduate programs preach students to reach integration and synergy, but the teachers themselves barely interact between each other.

[1]Cambridge Dictionary
https://dictionary.cambridge.org/us/dictionary/english/synergy

This Innovative to Practice Work in Progress paper is an effort to enhance the teaching and learning of mechatronics design. In times when knowledge disperses into different topics, it becomes more important to learn and understand to work within multidisciplinary teams, either as a teacher or as a student.

This paper is written according to the following description. Section II reviews related work around curricula and the importance of practice and integration. Section III brings the context of the study case. Section IV describes the approach upon which the academic synergy has been fullfilled. Section V opens the discussion of the results obtained so far, while Section VI finishes with the future work.

II. Related work

A. Problem Based Learning

In todays's education is not sufficient to have theoretical courses, but also practical experiences [3]. Moreover, traditional education in enginering design has deficits when compared to Problem Based Learning (PBL). First, the fact of inefficient knowledge reception when the education is limited to accoustical and visual presentations. Second, the fact that social competences cannot be taught theoretically. These deficits have led to an increase on practical activities as part of engineering education [4].

Many examples can be found in the literature about practical work, whether called PBL, Interdisciplinary Problem Based Learning (IPBL), Hands On Laboratory or Development Project. One example is described by [2], where a supplemental course was piloted to the curriculum of a Make to Innovate program (five year) in order to aid in the professional development skills (e.g. teamwork, communications, leadership, diversity, and ethics). This program is open to other students outside the Engineering College, allowing the interaction with a variety of projects and students. Another example is described by [3] through an academic project in power electronics. It highlights the importance of these experiences to attract new students and increase their interest in engineering.

This kind of framework is also common for interdisciplinary programs. For instance an academic space project is explained by [5] using IPBL. The overall project is divided into teams,

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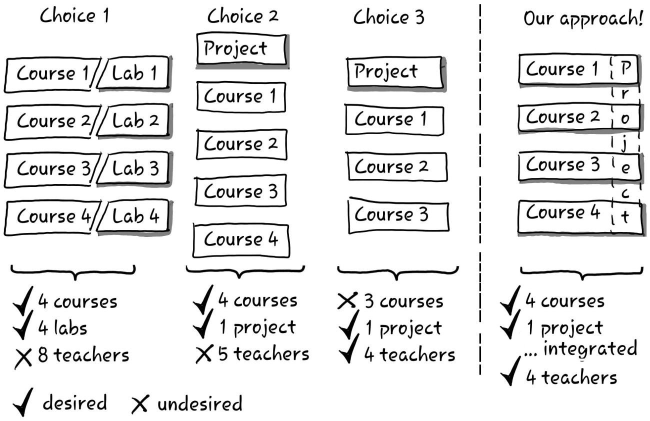

Fig. 1. Curriculum choices.

each of 4 to 5 students, through 17 weeks and implement the SCRUM, a framework for software development. Additionally, this approach has been introduced during the redesign of Mechatronics programs, such as the one described by [6].

Within engineering, mechatronics has a handicap that becomes an opportunity: it can only be effectively designed and developed by a cooperation of numerous engineers from eventually different disciplines [4]. This cooperation is achieved by the creation of project teams. And if a PBL is performed through teamwork, it resembles real world situations and problems that students will meet during their careers. Therefore, integration plays a significant role.

B. Integration

The importance of integration has been studied by [7] through three factors that impact the student's perception: (i) relationships among Math, Physics and a Project/Engineering course, (ii) relationships among professors, and (iii) relationships among professors and individual students. The study concludes that through an Integrated Course Block (ICB), high levels of interdisciplinarity and integration contribute to positive learning experience [7].

After reviewing the related work, the curriculum design choices are summarized on Fig. 1. In this figure, the choices on the left either (i) lack the integration of teachers, (ii) increase the number of credits that students must pay or (iii) leave behind important courses. Our approach is the one on the right.

Thus, the contributions of this paper are focused on (i) an Integrated Mechatronic Project (IMP) underneath the curriculum that neither requires the students to pay for additional credits nor displaces other courses and (ii) a methodology that eases the coordination accross courses.

III. Integrated Design of Technical Systems

The study case of this paper has been performed within the postgraduate program Integrated Design of Technical Systems (IDTS) offered by the Product Design Engineering (PDE) department at Universidad EAFIT. It consists of 8 courses, 4 per semester (18weeks) as shown in Table I. Students can take from 1 to 8 courses depending on the case (Table II). This strategy allows them to share courses with students from different levels. In anycase they must allocate 144h for each course, distributed according to a *lecture* to *self study* ratio of 1:3, in other words 36h of lectures and 108h of self study.

The courses of Table I were chosen based upon the structure of a mechatronic system (Fig. 2). This curriculum design eases the identification of each course's domain and the borders beyond which the other courses take over, a novel and coherent way to teach and learn technical systems [8]. Additionally, the physical infrastructure that supports the IDTS program is technology oriented. It is an open space laboratory, that facilitates the interaction [10].

TABLE I
COURSES OF IDTS.

Semester	*Code*	*Name*	*Credits*[a]
1	ID0615	Mechatronic Conceptual Design	3
	ID0616	Technical Programming Languages	3
	ID0617	Actuators and Sensors	3
	ID0618	Process Interface Equipment	3
2	ID0620	Power Electronics	3
	ID0621	Advanced Digital Systems	3
	ID0623	Control of Mechatronic Products	3
	IM0607[b]	Technical Systems Design	3

[a] One credit requires 48h/semester.
[b] Shared with another postgraduate program.

TABLE II
STUDENT CASES.

Case	*Description*	*Courses*
1	Undergraduate students that take courses from IDTS as complementary.	1 to 3 courses from 1st sem.
2	Undergraduate students at their last semester that take the minor in IDTS.	4 courses from 1st sem.
3	Postgraduate students that enroll in IDTS.	8 courses
4	Postgraduate MSc. students.	1 to 8 courses

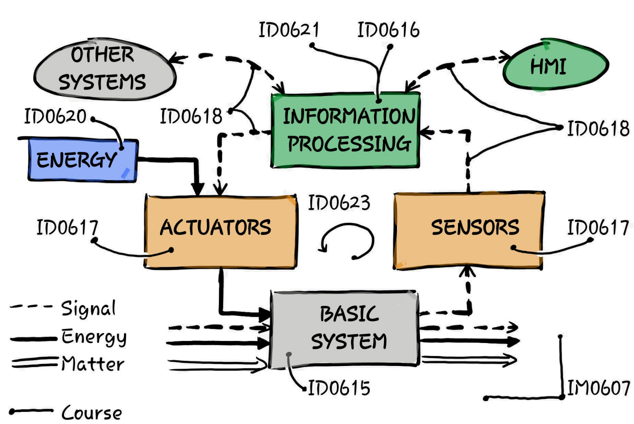

Fig. 2. Mechatronic system structure. Adapted from [8] and [9].

TABLE III
IMPs DEVELOPED BY THE STUDENTS.

Application Field	*Project's title*
Agriculture	Quadcopter pesticide sprayer Automatic indoor greenhouse Coffe bean sorting machine Leaf disease identification
Mobility	Hybrid motorcycle Lights tilting device Road's quality supervisor
Industrial	SCARA doughnut factory Omnidirectional platform Automated Guided Vehicle Book organizer Automatic toolbox
Health	Mechatronic prosthesis
Robotics	Salamander Snake Bar tender

IV. Approach

Despite the fact that IDTS began in 2011, we started implementing this approach by 2015 which was a critical year in terms of student enrollment into the 2nd semester (Fig. 5).

A. Integrated Mechatronic Project

An IMP was proposed underneath the courses (Fig. 3) in such way that students don't need to pay extra credits for a project course, without missing the courses' contents. Simoultaneously it is a good excuse for the teachers to build together the guidelines that the projects have to meet for each course. Furthermore the project ties all together even in the event that the courses don't relate to each other [7].

Project proposals come from three sources: research projects from the faculty, initiatives from the students themselves and industry needs. The proposals must meet the following requirements: the "client" must present a brief of the project by the beginning of the semester, the objectives must be fullfilled within 18 weeks, the project must have "ingredients" from the four courses (Table I) and the achievable Technology Readiness Level (TRL)[2] should be between 3 and 4.

Table III shows some examples of the IMPs developed by the students. Furthermore media is available at the program's website[3].

B. Integrated Schedule

The schedule of the courses from 1st semester (Fig. 3) has been designed in order to meet 5 milestones from a methodology domain, specifically the V-model [1]:

- Week 03: Product Design Specifications (PDS)
- Week 07: Conceptual Design
- Week 10: Detail Design
- Week 14: Verification
- Week 18: Mechatronic Prototype

[2]Wikipedia
https://en.wikipedia.org/wiki/Technology_readiness_level
[3]http://www.eafit.edu.co/programas-academicos/posgrado/especializacion-diseno-sistemas-tecnicos/proyectos/Paginas/proyectos-integrados.aspx

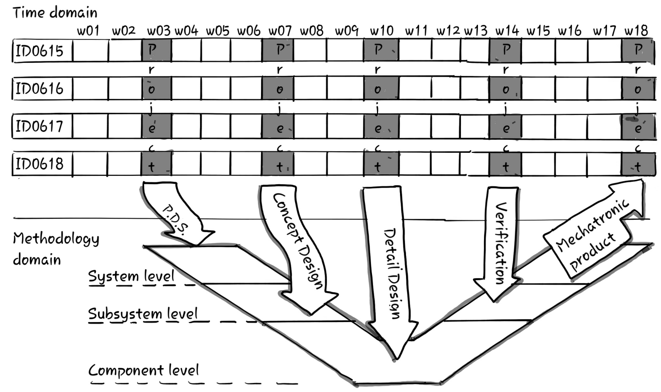

Fig. 3. Schedule of IDTS's 1st semester. V-model adapted from [1]

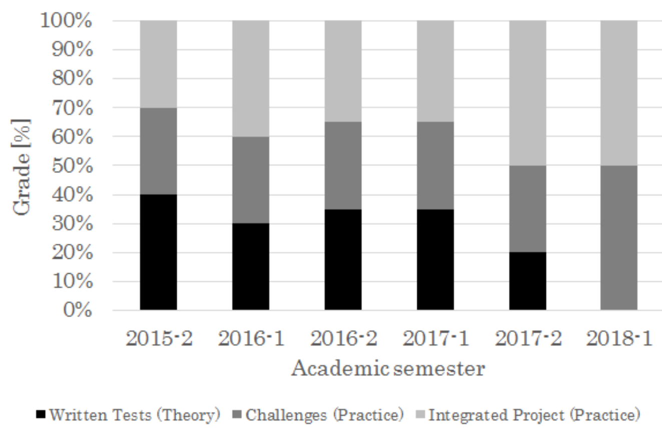

Fig. 4. Evolution of the grading distribution.

At these milestones each team of students is given 20min to orally present the IMP to the other teams and the jury (the teachers of the 4 courses). At the end of each presentation, feedback is given to the students. This is a crucial part of the process, since feedback is heard from the other teachers, and contradictions may appear. It brings to practice the concept behind 21st century schools [11], where students do not have 4 courses with one teacher per course, but 4 teachers for four courses.

C. Integrated Assessment

The type of the assessments and its grade's weight has to be uniform, in order for the students to allocate the same amount of time for the IMP on each course. This has been tuned with the feedback from students (Fig. 4). Initially, traditional education assessments such as written tests were performed, but nowadays they have been removed. The weight of the IMP is 50% of the courses's grade, and is the result of the average given by the 4 teachers.

TABLE IV
STUDENTS BACKGROUND OF CASES 1 AND 2 FROM 2011 UNTIL 2018.

Undergraduate program	%
Computer Science Eng.	3%
Industrial Eng.	4%
Physics Eng.	9%
Product Design Eng.	28%
Mechanical Eng.	56%

TABLE V
STUDENT CASES AT 1ST SEM. COURSES OF IDTS FROM 2011 UNTIL 2018.

Case	*Level*	*Courses*
1	Undergraduate students that take courses from IDTS as complementary.	10%
2	Undergraduate students at their last semester that take the minor in IDTS.	61%
3	Postgraduate students that enroll in IDTS.	15%
4	Postgraduate MSc. students.	14%

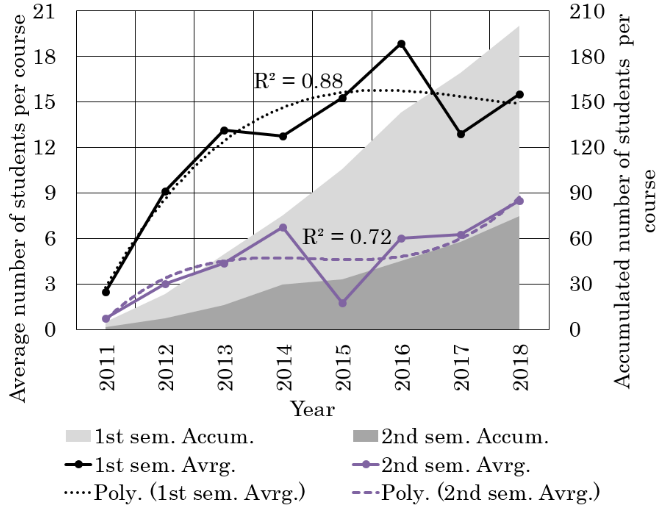

Fig. 5. Average number of students per course of 1st semester and 2nd semester.

V. RESULTS

A. Student perception

By the end of 2017 a survey was made among students about which assessments they considered to be more learning effective. At the end 57% answered the IMP, the other 43% picked practical challenges, and 0% chose the written tests. This is how the assessment's evolution shown in Fig. 4 came finally to the point where only practice is evaluated.

B. Multidisciplinarity

Sharing courses with other undergraduate and graduate programs has led to have students from different disciplines (Table IV), enriching the experience, and bringing clues to the question on how to ensure diversity in the programs and professions [12].

C. Multilevel

The approach previously mentioned has also led to have students from different levels (Table V). This has the advantages such as the fact that postgraduate students benefit from (i) newer knowledge from undergraduate ones and (ii) the fact that the latter know by heart logistics within the campus. In the other hand undergraduate students benefit from the experience and real world necessities brought by postgraduate students.

D. Student population

The average number of students per course is summarized in Fig. 5. The first semester courses reached a steady amount of 15. In the other hand, the behaviour of the second semester reached a minimum in the year 2015. After having such enrollment reduction, we decided to implement the IMP along with the approach explained in Section IV. It had a positive effect on the students and encouraged them to continue as postgraduate students in IDTS.

E. Intangible results

Indirect teaching has been allocated efficiently through the assistance of teachers at the oral presentations. Moreover, the time required for the design of written tests and its assessment has been relocated into IMP coaching. By using an integrated schedule the teachers have been able to (i) acknowledge the topics been taught by the others, (ii) avoid lecture redundancies and (iii) understand better the hollistic goal of the IDTS program. Students in the other hand have been able to learn from their teammates, and from teaching others their backgroud disciplines.

VI. DISCUSSION AND FUTURE WORK

The implementation of the IMP does not represent additional cost for the students, as they don't need to pay for extra credits. Additionally, the program didn't have to change its curriculum, as the same courses are being given. This is indeed one of the synergies claimed with this work. It has also possitively encouraged the students to continue their postgraduate program (Fig. 5), a fact of big relevance within an era when fewer engineers opt for further technical education.

By merging the time domain of the courses with the methodology domain, students and teachers were able to synchronize the courses. Each milestone increasingly demands results of the IMP development.

Decisions such as the removal of the written tests has helped to increase the learning effectivity. As students demanded, the entire assessment has been left to practical activities.

For future work, additional indicators of synergy must be designed and measured. Variables such as the resource allocation (e.g. time and money) are important to track for both students and teachers. And the measurement of the effect of the student's engineering background on the IMP's result.

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