TEACHERS’ REPRESENTATIONS ABOUT COMPUTATIONAL MATHEMATIC FROM A COMPLEXITY PERSPECTIVE IN MECHANICAL ENGINEERING CAREER

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Abstract

At the beginning of 1950, Computational Mathematic (CM) arose as an area of applied Mathematics. It includes the design of informatics architectures and the study of algorithms for modelling engineering process through differential equations sustained by a mathematical theory seeking the understanding of non-linear phenomenon included into models and challenging the computational methods.

CM and the new technologies of Information and Communication (NTIC) have changed the links established with the ways of teaching-learning, and they impact on the academically activities related to Mathematics. Both, MC and NTIC, affect the understanding of teachers about the theoretical and methodological developments and about the applications of complexity perspective, to promote an interdisciplinary approach of curricular contents of study schedules and aiming to train professionals who able to solve complex models using technology. Therefore, the tool/instrument to observe and measure and the theory which we think Mathematics are essentials.

Recent experiences enable us to rethink how CM emerges at epistemological substrate of Engineering and which is the empowerment and priorities of teachers with the CM. In this work we ask how the interaction of informatics systems is at Educational context, and which kinds of representations the teachers have when applying computational tools.

This work has two objectives: a) To analyse the teachers’ representations about CM and NTIC in Mechanical Engineering (ME) grade career, and b) To review study curricular guidelines and different paradigms for teaching Mathematics at our University (NTU).

The research methodology adopted is through a hermeneutical-dialectic study. A survey was carried out with n=24 teachers of superior cycle of ME grade career at NTU Rosario city (Argentina). Superior cycle was defined as a teacher dictating signatures of ME career (3rd, 4th or 5th year). Survey was instrumented with a pre-structured questionnaire. The answer alternatives were analysed.

Results show that just 90% of teachers surveyed use the computational tool as spreadsheet and calculus software, simulation programs, presentation alternative programs (Power-Point, Prezi) and fundamentally as a virtual campus; 22% of teachers apply the informatics tool as a direct substitutive tool, 11% use them as modification tool, and remaining 11% as restitution tool. Only 25% of surveyed teachers participate in monthly meetings of Departmental Councils; somebody should not be correlative subjects to keep attending to upper years, arguing that those unnecessary situations induce students to abandon the career.

As a conclusion, teachers from superior cycle of ME grade career show a weak empowerment with CM. Computer has become an instrumental and utilitarian device, when compared to traditional conservative models. Teachers surveyed did not identify the value of CM integration for the solution of complexity problems inherent to ME. This survey provided relevant information about curricular transformations: the evolution of some subjects of ME call for the need of a critically review as well as a revision of perspectives of instruction use which CM requires.

Keywords: Computational mathematics, complexity, educational strategies, mathematical education.

1 INTRODUCTION

There are multiple ways to incorporate informatics into the learning of Mathematic, and probably all of them have valuable reasons. The use of technological instruments facilitates making more explicit the role of representation forms. Particularly, the way in which the complementarity among graphical,
numerical, symbolical, algebraic and simulation aspects, exposed in previous experiences help to
develop the process of understanding, generalization and validation of mathematical knowledge.

Computational Mathematic (CM) arose as an area of applied Mathematics at the beginning of 1950s. It includes the design of informatics architectures and the study of algorithms for modelling engineering process through differential equations, sustained by a mathematical theory seeking the understanding of non-linear phenomenon included into models and challenging the computational methods[1].

In reference to CM, Donald Knuth (1974) highlighted the pedagogical value of algorithmic perspective; for him, to appropriate, build and analyse algorithms was more than a program elaboration, it was an essential of general proposal tool with which students may understand other signatures easily. Claiming the algorithmic approach, for Froilán Dopico (2007) CM is a set of programs, algorithms, techniques and theories with the responsibility of filling, through the developing of innovate algorithmic, the existing hole between the computer’s ability and the applications that must be executed. For Leoncio Ibarra-Martínez (2014), the programming languages -there are as many as paradigms in which they are based- are the mathematic of this century so as to formulate or build new abstract mathematical models. The variables of this new models are mostly discrete and approximate, neither deterministic nor finite variables [2], [3], [4].

CM and the new technologies of Information and Communication (NTIC), have changed the links established with the ways of teaching-learning, and they impact on the academically activities related to Mathematics. In that sense, Luis Moreno-Armella (2010) distinguished the use of computer as a tool and as an instrument [5]. Therefore, the tool/instrument we use to observe and measure are essentials, as well as the theory with which we think Mathematics.

We have used that same differentiation in a recent experiences [6] [7]. Conclusions from them lead us to ask again about: How CM emerges at epistemological substrate of Engineering? Which is the empowerment of teachers with the CM and what they prioritize? its powerful mathematical engine, their user’s interface, whether they use it as a resource manager or if they consider the environment/reality interaction?

This work have two objectives: a) To review the teachers’ representations about CM and NTIC in Mechanical Engineering (ME) grade career, and b) To analyze curricular guidelines and different paradigms for teaching Mathematics at our University (NTU).

2 METHODOLOGY

According to nature of study, this applied investigation was a hermeneutical-dialectic study [8], designed to evaluate the teachers’ representations about the curricular guidelines on mathematical formation,

A survey with 24 teachers from superior/advanced cycle of ME career at NTU from 2014-2015-2016 years was carried out. A teacher from superior/advanced cycle was defined as a teacher dictating upper signatures of ME career (3rd, 4th or 5th year). The teachers represented 54% of Chair/Head of the Institution.

Teachers participated answering a survey, instrumented as a pre-structured questionnaire. The alternatives answers were compared and contrasted.

This investigation was a part of my thesis presented for acquiring a Master of Teaching University degree, at National Technological University of Argentine, named “Multidiscipline in engineering education: Methodological changes for the approach to complexity by means of computational mathematic”[9].

3 RESULTS

3.1 Survey data

Teachers were asked about the way they used the computational tools. Just 90% answered that they used them as spreadsheet and calculus software, simulation programs, presentation alternative programs (Power-Point, Prezi) and fundamentally, as a virtual campus (Fig.1).
About the question about types of informatics tools usually included in learning process, one of three teachers (1/3) affirmed use some specific software, 33.3% referred applying calculus software as an auxiliary tool; one third mentioned the internet search engines. Less frequently were mentioned the use of virtual campus, digitalized material or another software (all of them are available at Mathematical Department library). Moreover, the evidence suggested that computational tool is not used as a facilitator media such as inter/transdisciplinary knowledge for the engineering problems approach. Again, it is noted that computational tool is at service of theoretical contents to develop in the different disciplinary areas (Fig.2).

Using Moreno-Armella’s classification about the user of computer, 22% of teachers from advanced cycle applied the informatics tool as a direct substitutive tool through introduction of functional improvements in the developing of signature; only 11% revealed that use some tool as modification, giving sense to learning activities that include informatics hours or modifying the experience (Fig.3). Looking at the Figure, a utilitarian vision of computers predominates, in concordance with the classic conservatory reproduction model guidelines.
Figure 3. Use of computational tools by the teachers from superior cycle in learning process

The question about which didactical strategies with mathematical software used the teachers for keeping students link mathematical concepts with contents of other signatures was answered as follow: 1/3 expressed that they did not anything strategies taking into account this objective. Other teachers (22%) mentioned the application of software as calculus tool in practices classroom; 12% did not specify their use (Fig. 4).

It was evident that a disciplinary vision predominates where the computer acquired mainly an instrumental character. The need of more communication with other teachers from initial cycle is claimed, to coordinate curricular signatures, to avoid the overlapping of curricular contents, with the deal of improvement the engineering student formation.

Figure 4. Didactic strategies with mathematical software applied by teachers to keep student link mathematical concepts with curricular contents of other signatures

By comparing the responses of teachers from superior cycle with the basic cycle (1st and 2nd year) (previous experience data) about the changes implemented in the transmission of knowledge and education with the incorporation of computational tools, it was reported that the situation is similar at both educational levels.

They stated that the introduction of such tools allowed students to obtain a greater capacity for abstraction, a long-term fixation of knowledge and a greater understanding of the contents through visualization and comparison. Teachers from basic cycle raised the existence of changes related to a human aspect: the interaction between the teacher and the student – and/or between students-, as well as the work environment. Changes of this type are linked with a higher levels of socialization and exchange of experiences between teachers and students, resulting in a better transference of knowledge, and that these tools gives to student the possibility to deep their experiences in research and development (Fig. 5).
When consulting about the potential changes in correlativity of signatures from curricular plan of ME career, mostly of teachers suggested that “Engineering and Society” signature, dictating at 1st year, should be not required correlativity to keep coursing signatures from 2nd year of ME career. Similar criteria was proposed for the signature Fundaments of Informatics, dictating in 2nd year, because its disapprobation impedes the coursing of Mechanical Engineering III (signature of 3rd year), and this situation induces students to abandon the career. Even more, teachers asked if Fundaments of Informatics should be a signature in 1st or 2nd year of career.

Asked them if signatures of initial level of career (1st and 2nd year) might facilitate the understanding signatures of superior level, somebody answered that the current planning and contents are enough; other teacher suggested to consider that basic signatures like Mathematic and Physic should show it with examples of application to specific mechanical issues. Other proposed the develop of issues referred to physic and electricity and to enforce basic content like Optic and Thermic, to improve the developing and understanding of the signature named Fluid Mechanics.

3.2 Analysis and interpretation of information

3.2.1 From theoretical framework

Reviewing the historical development of CM, in aspects like mathematical execution process, an implementation of change of traditional model would keep the connection between Mathematics and Computer, as Moreno-Armella (2010) stated, that the instrument might modify the science [5].

As shown at Fig.6, we considered the ideal (left side) and the real (right side) potential of informatics systems to solve problems in ME career.

The broken arrow point-out the missing pedagogical pathway, one that is not yet travelled, which would include the problem of computational error in numerical calculus and its relationship with the architecture of computer. To approach the ideal, it would take that teachers visualize and use the computer not only as a tool (through applications) but also an element to develop numerical experiments.
3.2.2 From didactical application

To contribute to palliate the pedagogical shortage, at the Multidisciplinary Laboratory of Basic Sciences from our University, we have developed didactical experiences with students and presented them at Educational Congress [10], [11].

As examples, we refer to lector one experience with traditional model (left of Fig.6) and another one which seek overcome limitations of model applying the ideal model of informatics systems (right of Fig.6).

The first one studied the dynamic simulation of a servomechanism for the design of different control strategies (Fig.7), modifying variables since equation who model the system [12].

The other one was an exploration for the approach of complexity to treat the management of mathematic-computational knowledge (Fig.8). Inquiring over problems of complex domain, where naturally feedback links emerge like in non-linear dynamical problems, a codified factorial function was applied with a software in which the recursive aspect is taking into account and obliges to establish a stop condition, to make transparent the way computer proceeds, that is to interpret the codified internal procedures of software and their possibilities of changes [13]. In cases of computer algebra systems (CAS), if they are closed and private, if we are not able to access to internal algorithms, we can only get trained in the user’s interface [14].
Figure 8. Examples of codified factorial function with a software that considering recursive function, keeping clear the way computer works

3.2.3 From data survey

Following the same design framework used in other experience with students [7] and from the reinterpretation of surveys answered by teachers, we designed a matrix including enabling elements (facilitators) to break down barriers and difficulties (constraints) to promote methodological changes in engineering education considering CM from the perspective of complexity.

*Table 1* exposes the conditions and facilitators from the point of view of study object. *Tables 2 and 3* show them from the point of view of the interaction of subject and study object.

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<tr>
<th>CONDITION</th>
<th>FACILITATORS</th>
<th>CONSTRAINTS</th>
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<td>OBJECT</td>
<td>- Inclusion of informatics as a mathematical instrument.</td>
<td>- To incorporate CM perspective in basic signatures with complementary and in-class activities.</td>
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<td>- Educational investigations related to use of computational tool for evaluating actions and results.</td>
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<td>- New teaching profiles that apply the computational tools in learning processes.</td>
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*Table 2.* Conditions, facilitators and conditionings for methodological changes for teachers from superior cycle in ME grade-formation context considering the environment

<table>
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<tr>
<th>CONDITION</th>
<th>FACILITATORS</th>
<th>CONSTRAINTS</th>
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<tr>
<td>ENVIRONMENT</td>
<td>- Permanent and continuous formation.</td>
<td>- To evaluate new experiences critically to build mathematical knowledge using CM. To attend the educational innovation using NTICs.</td>
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<td></td>
<td>- Access to updated bibliography. Working with specialist professionals.</td>
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<td></td>
<td>- To update programming knowledge.</td>
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<td>- To access to new material resources (due to fasted technological obsolescence)</td>
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<td>- To generate activities to motivate students, which include creative approach in technological productions.</td>
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Table 3. Conditions, facilitators and conditionings for methodological changes for teachers from superior cycle in ME grade-formation context, considering the micro and macro environment.

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<th>ENVIRONMENT</th>
<th>MICRO</th>
<th>MACRO</th>
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<td>- To generate referential organizational frameworks.</td>
<td>- To generate new working areas.</td>
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<td>- To develop academic inter-departmental meeting.</td>
<td>- To fusion the practice with the theory: Laboratory Classrooms.</td>
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<td>- To conform teams of capacitation for trainers of trainers who showing interest in this transdisciplinary perspective.</td>
<td>- To rethink working areas as new open and close spaces, because the computational tools erase time-space barriers.</td>
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<td>- To integrate signatures by implementing new proposals of curricular innovation.</td>
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<td>- To communicate the activities.</td>
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4 CONCLUSION

The survey analysis provided relevant information about the curricular transformations.

Deeply pedagogical reforms are been executed, both in forms and ways to conceive a teaching-learning process in order to become significant for students.

In general, these changes of attitude did not adopted by all the teachers. Exists some kind of resistance to reforms when it requires changes in teaching methodology and making adjustments to enhance curricular contents, according to its evolution, that imply improvement in teaching, quality and efficiency, using computational tools that make visible the computer procedures. If we are not able to access to internal algorithms, we can only get trained in the user’s interface.

This work demonstrates that current educational model does not benefit the strengthening of institutional members with the computational tool autonomy.

At solving engineering problems, CM allows formulating and building the new abstract mathematical models. These stop being continuous space-time models to transform into discrete space-time ones.

This is a new way of observation by understanding its scopes and its limits; new methods of thinking, understanding the logic and software. Not so much a change of objectives, but the modes that disciplinary content are built by institutional actors.

From a complexity perspective, two big investigation aspects might undergo. One of them, from the institutional point of view, seeking to adapt the current normative to new social references conditioned by technologies. Another one, to question teachers about the previous mathematical knowledges when using computers as a mathematical instrument.

REFERENCES


