The integration of knowledge in the Mechanical Engineering career

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Abstract

The integration of knowledge into the scientific and academic disciplines is being increased as a consequence of the scientific and technological achievement and the complex problems that must be solved by the society.
This paper presents a study of the trenches on the integration of knowledge in the mechanical engineering disciplines and its relationship with this specialty. A holistic curriculum model based upon the integration of knowledge and the student's professional skills is obtained. This model has a new approach in the introduction of new subjects (knowledge), in the solution of professionals problems, and in the link between the University and the society. The theoretical basis of this model can be found in the Higher education Didactics laws , the sociological relationship : society – curriculum – university, and the Vigotski's historically – cultural approach. The author shows the implementation of the new methodology in one discipline of the specialty and its curriculum assessment . The ending results have been positive as much in the career as in other disciplines where the curricular methodology has been applied.

I. Introduction

The integration of knowledge is needed for the contents determination in the engineering curriculum due to the own characteristics of the engineering process, which is an integrated process and to the increased volume of the scientific technological information as well as the growing interdisciplinary problems.

The Applied Mechanics discipline in the curriculum of mechanical engineering at the University of Camaguey consists of seven courses. But each one does not solve the professional problems up to the end of the courses. This discipline offers important concepts, laws, mechanical models and properties about the subject matter in mechanical engineering (machines, industrial equipment and installations), which will be used by other disciplines. In this way, the knowledge system of this discipline was divided.

The main objective of this paper is to establish a model of integration of knowledge and its application in one discipline of the mechanical engineering curriculum :the Applied Mechanics discipline.

II. The integrating trends in the contents of the Engineering curriculum

The integration of knowledge is a recent process and in engineering, one of the youngest of the professions, it constitutes its distinctive mark: the integration. The integrating trends related to the engineering content had been developed for many years in the universities and these trends become more important in the beginning of the XXI century due to the growing interdisciplinary cross.

Many authors describe their experiences about the integration of knowledge in the mechanical engineering curriculum. This integration has different ways to link different courses and in different academic years .

Bordogna, Fromm and Ernst[1], describe an integrated continuum, with which the engineering human resources are formed and where the engineering nucleus is integrated and unified.

Larson et al[2], explain the curricular design of the mechanical engineering integrated courses named Fundamentals of Engineering I, II, III, where Energy, Materials and Systems courses are linked.

Hollister[3], describes two integrated courses teaching named Unified Engineering that has the following subjects: Static, Mechanics of solid and materials, Dynamic, Fluid Mechanics, Thermodynamics, Propulsion, and Lineal Systems.

Miller and Cooper[4] present an integrated model based upon the engineering practice in the mechanical engineering teaching.

Carr et al[5], describe the university experience where all the engineering branches have a common basis of integrated courses named Scientific and Mathematical Foundations I, II, III, in which essential calculus, physics, and basic aspects of the engineering are included.

Perdomo[6]establishes the integration in the mechanical engineering curriculum through the integrated projects with an interdisciplinary character, where the student can solve professional problems about projection, exploitation and construction.

Taking into account the experience of different universities the integration can be grouped in three directions:

- The integration to achieve the professional skills from the freshman year
- The integration of different courses (about basic sciences, sciences of engineering, social sciences and others) in different years.
- The integration throughout the solution of professional problems

III. The integration of the design in the engineering curriculum

One of the most generalized trends in the university is the integration of design in the engineering's content as one of higher priorities in the mechanical engineering departments.

Dally and Zhang[7] in the University of Maryland describe the integration of the design from the first year of mechanical engineering throughout a project approach in three phases: design, construction and assembly all of which were made by students.

Starkey et al[8] in the Purdue's University show the curriculum design of one freshman course of mechanical engineering where basic sciences, Machine Design, Fluid Mechanics and others, are integrated.

Miller and Olds[9] describe one capstone course with a design sequence of two semesters. The course is based upon a multidisciplinary team work of students who are linked to the industry.

Wilczynski[10] shows the experience in one university where the design is included in many engineering courses.

Öztürk et al[11] in the University of North Caroline describe a new approach about the design engineering teaching for undergraduate students with the creation of a design center that is linked with the local industries and where the students perform real projects helped by computers networks for the preliminary design.

Gorman et al[12] establish the development of multidisciplinary learning modules for developing invention, design and creativity in the students.

Shaeiwitz et al[13] establish an holistic curriculum that has one fundamental skill: to design integrated in projects from the first year.

Diodati[14] describes one students' club based in the design of innovative devices. Cabona[15] establishes the integrating courses as curricular axis from the second year introducing design problems through projects. Diaz[16] describes the integration of students into the society problems through the projects solution.

H West[17] from the Massachusetts Technological Institute, presents an design analysis as a central axis of the mechanical engineering curriculum in many courses from the second year.

Evans[18] makes in his paper a bibliographical review from the principal reports, since 1920, from different universities, engineering societies and engineering organizations related with the engineering at the United States of America, about the trends of the introduction of the design as fundamental axis in the engineering study programs.

Ernst and Lohmann[19] summarize the financing research projects about engineering education based upon the introduction of the design in the curriculum and in this way they justify its significance in the last decade of the XX century and its influence in the XXI century.

The author of this paper takes these judgments and others universities' experiences to summarize and to extract the integration trends related to the design in engineering which are the following:

- The design as curricular axis in the integration of different subjects or disciplines and courses.
- The integration of the design for the solution of real professional problems by students and for developing the inventive and the creativity with multidisciplinary research team.
- The link of the design with different mechanical engineer functions as device construction, assembly and others.

III. The Applied Mechanics discipline. Its role in the mechanical engineering curriculum at the University of Camaguey.

The Applied Mechanics discipline is one of the most fundamental disciplines in the mechanical engineering career and its action field is to design machines, industrials equipment and installation and it's composed of the courses in Table 1

Table 1. The courses in the Applied Mechanics discipline

Academic year	I Semester	II Semester
2nd	Theoretical Mechanics I	Theoretical Mechanics II
3rd	Strength of Materials I	Strength of Materials II
3rd	Theory of Mechanisms and Machines	
4th	Design of Machine Elements I	Design of Machine Elements II

This discipline serves as basis of others disciplines of the career. It was designed according to the logic of science, that's why in the courses the students don't solve professional problems in each one, only at the end in the fourth year. The discipline must be changed, using the integration of knowledge and in this way the students can solve the design of professional problems from the second year.

IV. A model of integration of knowledge for solving professional problems according to the profession object.

Taking into account the previous situation the Mechanics Applied discipline was restructured according to the integrating trends and the holistic curriculum. In this case the curricular axis in the discipline is the machine or machine element design.

The principal idea in this model is to find professional problems concerning design whose solutions include the discipline contents. These contents are organized taking into account the main concept and the professional skill. The contents of the discipline' courses will respond to the categorical structure of the professional problems. The ending results in the curricular design of the discipline will be in correspondence with the relationship between the logic of the science, the logic of the assimilation process and the logic of the profession[20].

This model of integration of knowledge has the following theoretical basis:

- The logic science
- The laws of the Didactic of Higher Education
- The relationship between society – curriculum – university
- Vigotski's historical – cultural approach

The logic science in the Applied Mechanics discipline
The knowledge system of the Applied Mechanics discipline belongs to the sciences of engineering. Its origin is in the contradictory process between the development of science and the social practice. The knowledge system of this discipline has contradictory elements: the professional problems, the main concept and the professional skill.

The laws of the Didactic of Higher Education
The Didactic of Higher Education has some laws. One of them establishes the relationship between university and society. This law is verified in the integration of knowledge of the Applied Mechanics discipline. The introduction of new knowledge appears in dynamic and flexible way in this relationship. When the professional problem is frequent in the future professional life the introduction of the knowledge and skills associated to the professional problem in the undergraduate curriculum is justified. Another law in the Didactic of Higher Education is the one that relates the different components of the teaching process. For this reason it is necessary to apply, for example, new teaching methods and new objectives in the courses.

The relationship between main concept and the professional skill
The contents of this discipline need to be structured from the relationship between main concept and the professional skill. The engineering courses are a pedagogical arrangement between science and technology. The most important content is named main concept. It constitutes the content (concepts, laws, theories) that never changes in long time. The essential skills in the contents are the professional skill.

The historical – cultural approach in the integration of knowledge
This model starts from the historical – cultural approach applied to the dynamic of the education development where the concept of "next development zone" is related to the solution of the professional problems by students. This concept means that the students work in the solution of the professional problems helped by professors or by other students in team works.

Society – curriculum – university
The relationship society – university had influenced in the engineering curriculum and in the strategies for achieving an engineer who responds to the XXI century necessities.
In this model based upon the solution of professionals problems and in the knowledge integration, the relationship society – curriculum – university is included as the changing society of today has influenced in the professionals problems and in the university curriculum.

V. Stages of the integration of knowledge model

After describing the theoretical aspects, a methodological element is necessary.

The stages of this model has in its determination the previous analyzed theoretical basis[21]

Stages in the model of integration of knowledge in the discipline

- Determination of the professional problems from the social necessities
- Determination of the professional problems database using expert method or other sociological techniques
- Determination of the required contents for solving the professional problem
- Epistemological analysis of the discipline using conceptual maps
- Determination of the main concept of the discipline
- Determination of the relationship between the main concept and the professional skill
- The introduction of new knowledge in the discipline contents
- The new structure of the discipline according to a specific methodology
- The validation of the proposed knowledge systems

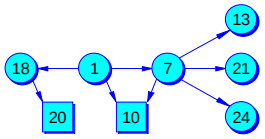
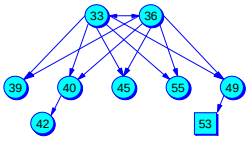
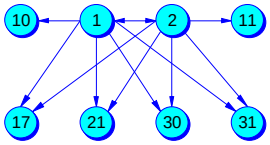
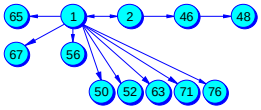
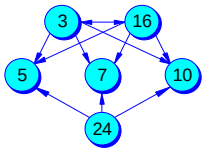
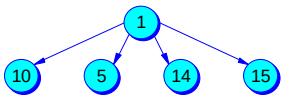
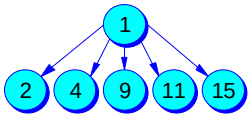
VI. Curricular validation

Taking into account different approaches in the model of validation it is proposed in this research to assess the following aspects:

- The knowledge system and the skill system checking, both referred to the discipline.
- The justification about the introduction of new knowledge in the discipline.
- The students' contents assimilation by means a pedagogical experiment.
- The application of this general methodology of integration of knowledge in other disciplines and careers.

VII. The principal results about the application of the model in the Applied Mechanics discipline

1. The curricular study of the discipline was made for obtaining the main concept by using the conceptual maps. Newton's laws are the main concept in the discipline. Figure 1 shows the conceptual map of the Applied Mechanics discipline.

AY(*)	I Semester	II Semester
II		
	Theoretical Mechanics I	Theoretical Mechanics II
III		
	Strength of Materials I	Strength of Materials II
III		
	Theory of Mechanism and Machines	
IV		
	Design of Machine Elements I	Design of Machine Elements II

(*) Academic year

Fig 1 The conceptual maps in the Applied Mechanics discipline before

2. The professional problems were grouped in six in correspondence with the most frequently found in the social context. Figure 2 shows the groups and its principal professional problems.

Group I	Design of a translation screws or the machine members
Group II	Design of metal structure Design of pressure cylinders
Group III	Design of shaft and its couplings
Group IV	Design of mechanisms
Group V	Design of the basic members of a single machine
Group VI	Design of the basic members of machines with some complexity, and other devices

3. The courses in the discipline were improved, as much in the quantity of hours, as in the number of courses. In the new restructured discipline the number of courses is now six. The courses has a new name too. Figure 3. shows the new courses in correspondence with the professional problem which must be solved in each case.

New Course	Professional problem
Applied Mechanics I	Group I
Applied Mechanics II	Group II
Applied Mechanics III	Group III
Applied Mechanics IV	Group IV
Applied Mechanics V	Group V
Applied Mechanics VI	Group VI

Figure 3. New courses in correspondence with groups of professional problems

4. The courses' integrated programs were elaborated for solving professional problems each one.

5. The new knowledge related to the discipline was introduced: experimental methods and the Finite Element Method. This was done in an integrated way in order to optimize the design.

6. The integrated programs' validation was made with mechanical engineering students groups during two consecutive academic years and its results were significant.

7. In the pedagogical experiment the following indicators were used: the quality of the professional problems solution by the students, the diversity of the professional problems types, the diversity and the increase of the professional problem types, and the academic efficiency.
   The tests of the non parametric statistics and parametric statistics were applied: Kruskal – Wallis, square chi, and others for studying the different indicators.

8. The methodology was validated in other universities with good results as well in the curricular aspects as in the pedagogical experiment with students.

VIII. Summary

This paper describes the trends of the integration of knowledge in the mechanical engineering curriculum, in addition to the trends of the introduction of the design as a curricular axis in the programs.

A model of integration of knowledge was created and its theoretical basis was analyzed . These model stages were applied in the Applied Mechanics discipline for mechanical engineering students.

The model's effectiveness has been proved by different ways, as much in the epistemological analysis, as in its application with students groups.
The model has been introduced in other careers and disciplines with good results.

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