Directions and Challenges in Engineering Education under Complex Approach towards Knowledge Society

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Abstract — XX century culture has emphasized specialization paradigm in all knowledge domains, including Engineering one. World culture, naturally, has increased complexity on globalization times putting real challenge to educators looking for an International Engineer profile for XXI century. On this direction, this paper presents core aspects from a knowledge based educational model - Thematic Oriented Methodology - which is centered in complex modeling axis just to treat knowledge domain. This methodology theoretical orientation, is in accordance with Complex Thought research from UNESCO Edgar Morin itinerant cathedra for XXI century education. The present proposal combines those generic principles enounced by Edgar Morin, and a concrete knowledge modeling tool, born in Informatics - Object Oriented modeling tool. From complex information systems, this informatics tool can be, yet, applied at educational perspective. The central axis of Thematic Educational Methodology is knowledge treatment as a complex system, integrating vertical and horizontal knowledge categories. This facilitates pedagogic and harmonic integration of contents, from abstract issues like social, ethical and cognitive to concrete issues like math’s and physics, or even computer programming. Here, it seems crucial to discuss about a definition of complexity that is, at first, quite ambiguous word, if they are considered different kinds of knowledge paradigms. Definition of complexity, under open knowledge paradigm, added with complexity of object of study definition, constitutes a contribution to international perspective in Engineering curriculum. They are presented some practical examples combining abstract and concrete issues related with an Informatics discipline for Engineering course beginners. It is presented an example of thematic definition for a complex project in Environmental Engineering. Finally, it is analyzed the presence of technology as educational tool support and what is the role of Informatics in techno carriers. Informatics can be, not only a concrete tool support, but much more. it can, also, be a potential tool for complex systems modeling like Engineering educational system. Putting all together is the aim from XXI integrative spirit in Engineering education and also from the presented methodology.

Index Terms — Engineering Education, Thematic Oriented Methodology, Object Oriented tool, Complex Thought, Integrative View.

INTRODUCTION

“Knowledge is organized for a purpose and reflects the world view of the authors in terms of corporate values, power structures, objectives to be achieved, etc. Uncritical acceptance of such material would make us brainwash ourselves. What we need was a re-examination of information technology based upon the world view, emphasizing solidarity, industrial democracy, safe employment, safe working conditions, decent wages, etc”
Professor Kristen Nygaard [10]

Presence of technology on modern civilization has been a central discussion point on several scientific forums, all over the world. A deep question in education is how to organize contents, such way, students can develop both, analytic thinking, required in focused knowledge aspects, and synthetic thinking, required on multifocus knowledge aspects. The aim is to stimulate students to learn to face very complex themes, typical from globalization times.

This paper presents an open educational proposal centered in knowledge modeling. So, a core aspect is how to treat knowledge on, day by day, activities. Synthesis between generic knowledge and specific topics is enhanced by this proposed educational methodology, called Thematic Oriented Educational Methodology [1]. This educational approach is aligned with ABET criteria 2000 [2] for Engineering careers which emphasizes synthetic vision in education. Synthesis approach is also recommended on several documents from UNESCO Itinerant Cathedra for Complex Thought, titled Edgar Morin Itinerant Cathedra [3]. Thematic Oriented methodology has been, already, discussed among ICEE Conferences, from year 98, 99 and 01, [4]-[6]. Thematic Approach is supported by a modeling tool to treat knowledge open way. This modeling tool’s name is
Object Oriented. It is well known at Informatics domain, but it can go ahead, towards educational area, just looking for broad themes modeling, not necessarily to be implemented in a computer system. Some pedagogic examples are presented to just to illustrate this tool potentiality at educational domain. Conclusions points out harmonic integration between open model and engineering thematics vision, at synthetic perspective, an expected value for XXI century professional profile.

**THEMATIC ORIENTED METHODOLOGY - A COMPLEX APPROACH APPLIED TO ENGINEERING EDUCATION**

Central idea from Thematic Oriented methodology is to lead with a chosen thematic enough wide to have a long life cycle. Thematic, or object of study, must be defined as a complex object. Complex vision refers to combination between generic knowledge categories, including ethical, ecological, social, economies issues, or, whatever is discussed with students with specific aspects, like implementation tools as math’s, physics and computer science.

Object of study is defined as a Thematic of real world, to be modeled and implemented during a pedagogic life cycle (discipline, set of disciplines) considering a disciplinary oriented curriculum. Thematic Oriented perspective, first of all, is a theoretical formulation for a wide range of pedagogic implementations. Each particular implementation must define all teaching details, like pedagogic instrumental options and others respecting different knowledge paradigms.

**Complexity x Difficulty**

Following Morin, *complexus is what is treated together with its wide context* [7]. From this definition, it is important to distinguish between complexity and difficulty. Complexity related with open models is synonymous of interdisciplinary knowledge approach. It is related with wide abstract knowledge categories. Complexity related with closed models is synonymous of disciplinary knowledge approach. Complexity, interdisciplinary sense, constitute open abstract knowledge categories which embed close concrete knowledge categories. Concrete categories, by their side, can, also, embed abstracts, theoretical formulations, but, they concern to part categories, branch from open ones. If it is mentioned complexity referring to part categories, it is better to call them 'part complexity', or, difficulty, or some other word, just to avoid ambiguity. So, complexity term has been ambiguous applied to both, closed /disciplinary focus, and, to open/ interdisciplinary focus. It is to take care about complexity signification. Complexity must, first, ask, what kind of knowledge paradigm are been thought? It is related with open or closed knowledge paradigm? It is, somehow, important to add that open models are not opposite to close models, because close models are branch/part categories from open models. They live together, and complementary way, in harmonic complex models.

**Relation between Thematic Methodology and Complex Approach**

Thematic Approach considers knowledge context as a complex open model. On this direction, thematic axis is a kind of educational guideline, which affects educational process and curricular organization. Following complex approach, at curricular level, for example, basic sciences disciplines will be treated as specialized contents and not as isolated introductory content. In this sense, numerical methods, physics and math’s contents appear, without details or independence from engineering contents configured as thematic project, on the first versions of the model. A first model/project version, is a kind of template to refine contents a posteriori. Later, as time goes by, advanced project versions include more detailed contents from basic science. This way, relevance of those contents is reinforced. It is suggested insertion of more specific contents later on the course schedule. Anyway, they are treated at fresh man curriculum in a simplified, but integrated way, with abstract questions like engineering at globalization times, or some other broad topic.

**WEDDING FROM THEMATIC APPROACH AND OBJECT ORIENTED MODELING TOOL**

After defining object of study, as a Thematic that covers a complex open knowledge domain, it comes a second step. This step is related with thematic practical implementation, to be solved step by step.

Thematic is represented by a model including several knowledge categories to be distributed in different teaching issues. It becomes necessary a tool support for building harmonic model for those concrete aspects solving. What kind of tool could be useful to modeling those knowledge categories under complex thematic approach?
Thematic pedagogic axis finds a natural link with Object Oriented Modeling tool. The principles of Object Oriented modeling, derived on the years 60, by professor Kristen Nygaard [8] from Department of Informatics from Oslo University, are usually applied in advanced software development modeling. In this case, modelers usually have enough programming skill focusing software design aspects. Nowadays, Object Oriented principles are migrating, not only, to informatics beginner’s level, but also, to other undergraduate courses like engineering, or even at high school. This is a great merit of those ideas, derived fourteen years ago. Object modeling tool potentiality is to treat open knowledge domains. However, it is, still, predominant applied at very specialized informatics issues. It is perceptible that those Object Oriented principles align themselves, also, with generic educational proposals for the XXI century education, by complex thought proposals.

**Thematic and Project – Two Levels of Educational Approach**

Thematic Oriented methodology is knowledge centered and it can be implemented through several projects versions, as times goes by. Thematic can be called Metaproject. Metaproject embeds several project versions with several levels of difficulty from the same thematic development. Abstraction is first pedagogic principle to treat knowledge under project versions. Abstraction principle definition comes from Object Oriented modeling tool domain. It is called Zero operational principle. This principle just helps to look the same, and unique metaproject, at several stages of development (several projects). Each project version embeds increasing difficulty issues. Each project is a model, or an abstraction of reality, adjusted to pedagogic demands at different knowledge skills. This way, it is easy to implement a complex thematic, also in fresh man curriculum. Thematic proposal does not demand any kind special skill to students to begin the complex approach.

**ENGINEERING THEMATIC EXPERIENCE UNDER COMPLEX APPROACH**

Starting point of object definition is just to be chosen adequate thematic level of generality. It must support a generic knowledge domain just to include enough wide range of embed knowledge categories. Those knowledge categories are not only related with part knowledge complexity but also from wide areas, integrating social, eco, ethics and ICT knowledge domain. Thematic Oriented educational approach give to student, opportunity to look a same problem several times, under increasing difficulty levels. This is easier to apply at open structured curricula, known as project oriented curricula, than traditional sequential disciplines oriented curricula. But, any way, it all depends on the way the whole contents are treated by teachers team, under course support, including teacher team training to stimulate dialog and harmonic relation between different disciplines implementation.

Author’s pedagogic experience at UFSC university undergraduate courses including Engineering and Informatics courses concerns to a long period where many thematics have been developed with students.

Some examples of implemented thematics are:

- Transport Engineering (focus: collective transportation, economics, maintenance engineering, motor projects)
- Electrical Engineering (focus: light distribution public service, electrical engines)
- Arm Ministry (focus: social presence, costs, maintenance engineering)
- Aircraft (focus: society service, maintenance and machine development, weather studies)
- Environmental Engineering System (focus: meteorological studies, environmental politics, laws, national ministry, rain follow aspects)
- Environmental Engineering (focus: water studies, social importance, water treatment work station, physics chemical water studies)

It is interesting to remake that engineering knowledge domain offers good choices in terms of thematic because it is, somehow, natural to consider inter relations between technology, and, society demands when you are developing engines.

**EXAMPLE OF ENVIRONMENTAL THEMATIC PEDAGOGIC DEVELOPMENT**

The following example of thematic development concerns to Sanitary and Environmental Engineering domain of knowledge. Theme development: Environmental case. Concrete Model: Meteorological Studies. Focus: pedagogic activities towards synthesis from abstract and concrete aspects of a knowledge model as Meteorological studies of Environmental theme. Context: introductory discipline at Engineering and Informatics fresh man curriculum.
Abstract and Concrete Knowledge Integration at Environmental Thematic

They are available a wide range of pedagogic activities facilitating integration between whole (thematic) and parts (concrete issues) during thematic development. Here it will be analyzed three pedagogic aspects from Thematic modeling.

First pedagogic aspect: presenting disciplinary issues as part of interdisciplinary issues.

Second pedagogic aspect: enhancing vertical / horizontal knowledge categories under Object Oriented modeling tool support. Third Pedagogic aspect: exploring ‘whole mind’ integration between right and left brain reasoning.

Interdisciplinary to disciplinary knowledge movement

Figure1 to Figure 3 illustrate Environmental theme development at different moments. At a first moment, students can discuss about Environmental thematic very open way, without limits. They can express emotion, doubts and opinion through a draw activity, for example. After this, they arrive to design activities. They register through a class diagram schema what kind of knowledge will be treated by Environmental proposed model. Finally, they will dedicate themselves to solving problems tasks, using concrete knowledge as math’s, computers issues, and so on.

Example of some pedagogic activities to treat knowledge at Environmental thematic example:

- Abstract level activity: student draw, representing Environmental theme; (Figure 1);
- Concrete level activity: class diagram, from Environmental theme referring to meteorological study model. Model is represented by 09 classes (Figure 2);
- Very concrete level activity: piece of a computer program belonging to Array class; numerical method (method X1: First Grade Integral Calculus), to solve rain follow data issue at Pluviometric Department (Dpluvio). This department belongs to Meteorological station (Figure 3).

This activities sequence shows a movement from abstract to concrete knowledge issues.

Vertical and Horizontal Knowledge Categories Relationship

Figure 2 shows horizontal and vertical knowledge categories relationship. It is represented by a class diagram schema. Each class is represented by a box at class diagram schema. Ex. Work Station box is a category (Figure 2).

Example of vertical relationship between knowledge categories: Meteorological Station category, and Work Station category. It can be said Meteorological Station is a kind of Work Station. Work Station is more generic, Meteorological Station is less generic, but they are putted at same hierarchical line (vertical sense). They have a link, with external character, somehow independent, in terms of knowledge expression.

Example of Horizontal relationship between knowledge categories: Dept. HR (Human Resources Department) category, and Employer category. It can be said Dept HR class has Employers. Employer category is a branch from Dept. HR. It is a part of a whole. They have a horizontal relationship or link, with internal character. Employer is inner part from Dept. HR.

Whole Mind Reasoning – Right and Left Brain Reasoning

Whole brain reasoning activities can be added to Thematic Oriented proposal stimulating students learning process. Reasoning is divided in right and left brain reasoning. They can be traduced by “whole mind” activities by Scheele [9].

Examples of whole mind reasoning at Environmental thematic case:

- Right brain reasoning: synthetic thinking focused (Figure 1 / Figure 2)
- Left brain reasoning: analytical thinking focused (Figure 2 / Figure 3)

Figure 1 express visual, or, no linear representation (draw). Figure 2 express part visual, part sequential representation (class diagram schema). Figure 3 express sequential analytical representation (math method).
TECHNO CARRIERS TOWARDS XXI CENTURY PROFESSIONAL PROFILE

Techno careers profile development expects for an engaged citizen engineer, educated under complex vision. In this direction, Informatics domain of knowledge can contribute to those careers development, playing two different roles. Once as a concrete tool support, and, second way, as a theoretical knowledge modeling tool, named Object Oriented.

As concrete tool, Informatics represents a traditional support to many Engineering courses. It is welcome when they are needed high accuracy, high amount of data manipulation, risk processes simulation, robotics, or even, when it is needed to win long distances in communication systems.

As theoretical tool, Informatics can contribute to education, and to techno carries, through Object Oriented modeling applied at complex thematic context. This contribution is, not yet, so visible, but, it is total available by teachers from all domains of knowledge.

CONCLUSIONS

Thematic Oriented approach is a contribution to Engineering Education facilitating integrative view in teaching / learning educational project.

Thematic Oriented approach points out potentiality of informatics to modern education. It can use Informatics as concrete tools, but also, as an educational knowledge modeling tool support. Thematic Oriented proposal uses Informatics Object Oriented knowledge representational tool, yet applied to complex/open engineering models. Complex models integrate abstract values level, like insertion of technology in human life, till concrete implementation details, like a math method implementation. All can be treated together, as times goes by, given students engagement and satisfaction.

Thematic Oriented approach is knowledge based, supported by complex thought vision, favoring integrative spirit in Engineering Education, as it is expected for knowledge society.

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REFERENCES


FIGURES AND TABLES
FIGURE. 1
DEVELOPMENT OF THEMATIC VISION AT ABSTRACT LEVEL

ENVIRONMENTAL THEME - METEOROLOGICAL STUDY

LEVEL: ABSTRACT
KIND OF ACTIVITY: STUDENT DRAW
KIND OF REASONING: RIGHT BRAIN

FIGURE. 2
DEVELOPMENT OF THEMATIC VISION AT CONCRETE LEVEL

ENVIRONMENTAL THEME - METEOROLOGICAL STUDY

LEVEL: CONCRETE
KIND OF ACTIVITY: PROJECT CLASS DIAGRAM
KIND OF REASONING: RIGHT PLUS LEFT BRAIN

FIGURE. 3
DEVELOPMENT OF THEMATIC VISION AT CONCRETE LEVEL

ENVIRONMENTAL THEME - MATH METHOD DETAIL

Class Environment:
ARRAY = class dataX
(class of real data type methods)

method XI : (first grade IntegralCalculus)
doSum ( sum);
a = sum / 2 + element [ 1 ] + element [ n ]
integral = ( a ) * h / 2;

LEVEL: CONCRETE
KIND OF ACTIVITY: PROJECT ISSUE COMPUTER IMPLEMENTATION
KIND OF REASONING: LEFT BRAIN