Innovative Approach to Teaching/Learning Strategies in Engineering Education

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Abstract *- A worldwide problem in engineering education is the way teaching/learning strategies are developed and implemented in engineering courses. This paper argues that the problem may be approached by using innovative teaching/learning strategi es which are student centred. The arguments consider knowledge as a construction and reconstruction process based on phenomenological and hermeneutic concepts which are described in full. The approach fosters student/lecturer commitment and emphasizes cont inuous assessment of the process. Experiences mentioned in this paper have demonstrated the effectiveness of the proposed methodology.*

Index Terms *- Engineering Education, Hermeneutics, Phenomenology, Teaching/learning Strategies.*

INTRODUCTION

In order to approach the topic of teaching/learning process this paper takes into account two important issues: on the one hand, the assessment of theories on how knowledge process takes place and, on the other hand, people's conception about knowledge itself. This debate takes place within the epistemological field given that the focus is on knowledge as a way of understanding the lecturers' pedagogical practices. First and foremost this paper recalls the traditional studies that discussed the act of knowing as a relation between the subject who knows and the object of knowledge. This relation has its roots in the debate between rationalism and empirism which, despite being overcome in the philosophical field, still lingers on as a background for pedagogical practices in many schools that keep considering knowledge as being situated in one of the poles either in the subject or in the object. These views having been surpassed by the conceptions based on phenomenology and hermeneutics which in turn, despite presenting different approaches one another, make possible a complementary understanding of the teaching/learning process. These conceptions consider that knowledge takes place as an interaction process involving the subject and the object. Last but not least, as regards the conceptions about knowledge, the issue is whether it is an insight or a construction. Phenomenology leads to an understanding that knowledge is a construction process or, if a hermeneutic approach is taken, knowledge is seen as a reconstruction process. This paper tries to shed light on those issues, finding on them a conceptual basis for underpinning pedagogical practices and alternative methodologies applied to the teaching/learning process in engineering.

The paper presents situations where the proposed approach can be applied and it considers aspects such as: recover knowledge history; assess knowledge in the current context and start from students' previous experience to mention but a few. It includes a practical and successful experience, which took into account such issues - in actual engineering courses, - based on the concept of knowledge as a construction/reconstruction process.

KNOWLEDGE APPROACH IN THE RATIONALISM AND EMPIRISM CONCEPTIONS

According to Cortella [1], one of the crucial aspects of pedagogical practice is the conception about knowledge. In that sense it is necessary to consider the following question: "is knowledge acquisition a process that involves discovery or construction?" This topic is approached by considering knowledge as a process which sets up a relation between the cognitive subject and the known object.

The rational/empirical model brings the idea of knowledge as a discovery process, that is, a conception according to which truth and knowledge are hidden somewhere waiting for someone able to get there and discover them. This is a point of view that does not consider how the knowledge acquisition process takes place. In this case is knowledge (truth) in the subject or in the object? In order to answer this question it is necessary to consider the point of view of both philosophical theories which discuss this problem: rationalism and empirism.

For rationalism the source of knowledge is in the subject who knows as a result of one's deductive reasoning ability. In this conception the subject brings possibilities of self-knowledge and self-learning which manifest themselves on the object of knowledge (innate). In other words, intellectual development happens in-out, depends essentially on the subject, not on the environment, and refers to a subjective process. It is also argued that in the knowledge acquisition process the subject plays an active role and acts on the object of knowledge. The object itself is neutral and static and only receives the action from the subject.

According to the rationalist conception, the learning process consists of emphasizing those theoretical models in which value is given to what a subject thinks of reality. It considers memorization, intellectualism, deductive reasoning and ideas about things as valuable issues.

On their turn, the empiricists believe all knowledge comes from experience. Knowledge consists of an environmental act on the subject. External stimulus would be caught by the human senses which receive data or information coming from the object as if the object had the ability to transfer its essence to the subject, thus presenting reality as it is to the subject. The subject is passive, contemplative, being influenced and indoctrinated by the truths which come from the object. As opposed to that, the object is active and leads the act of knowledge. The mind, in this case, is a *blank sheet* where data and information of the external world will be recorded.

The focus of this learning process conception lies on knowledge resulting from experimental and measurable data. Knowledge validation is based on the scientific method applied – a model intrinsically linked to positivism. The active role played by the student is stressed and knowledge is acquired by action and experience**.** In other words, the phenomenon to be learned is in front of the subject, meaning the idea of the obvious fact.

In the Cartesian conception consciousness may reach truth by pure self-intuition, without the need to consider a relation with language and tradition. Nevertheless, the idea that the subject has of the world does not come exclusively from inside as if it would be part of the subject's nature. The subject's conceptions, language, values (that are already available when the subject is born and that are learnt by living in the world) by which the world is thought, result from a social process, that is, they are not private items of the subject, but rather inter-subjective.

In the empiricist conception "the *blank sheet* theory offers a poor and simplistic explanation of consciousness, without addressing the complexity of its ways and its intentions" [2]. It is not possible to experience an empty consciousness and more difficult yet to know its pure impression, giving that reflecting assumes a ready-made consciousness. In fact, the subject approaches facts, experience, and texts, by always bringing a previous comprehension. The facts faced by the subject become meaningful depending on the subject's previous knowledge of the world.

Kant tried to address this controversy between Rationalism and Empirism by advocating that thinking and experience are both sources of knowledge [3]. Following Kant's reasoning, in every knowledge act the ways of the spirit have a prior intervention as a condition for experience to take place. In other words, knowledge precedes experience; nevertheless thinking is what gives it a shape. On the other hand, experience is what actually provides the object of knowledge. The object, which is perceived by the human senses, is organized by thought since the previous elements of reason make this organization possible – this is a phenomenon that happens in the space and time of cognitive consciousness. In Kant's words, "to know is to know something" [4]. Human knowledge refers to the world of phenomena, not being possible to know the object itself. Kant's contribution to epistemology made it possible to introduce the concept of knowledge as a construction, since it considers that mind changes from a passive agent to act modelling, classifying and organizing the world. The later development of phenomenology takes into account this principle, according to which to know is to know something.

KNOWLEDGE CONSTRUCTION AND RECONSTRUCTION: A PHENOMENOLOGICAL AND HERMENEUTICAL VIEW

Phenomenology and hermeneutics enabled the observation that knowledge sets up a relation between the subject who knows and the object known, and therefore from such relation truth and wisdom emerge. Knowledge (truth) is neither in the subject only (rationalism) nor in the object only (empiricism) but rather in the interaction between them, that is, the knowledge that springs up from the relation between the subject who knows and the object of knowledge. Both subject and object are active parts of the process.

Phenomenology considers important the description of phenomena which appear to consciousness. Phenomenology theory "searches to describe the intentional acts of consciousness and of the objects addressed" [5]. Reference [6], referring to Husserl's studies, stresses that consciousness as intentionality is fundamentally aimed at something. This argument contrasts with the one which advocates that it is possible a pure consciousness. On the other hand, it does not exist an object itself, the object only exists for the subject who gives it a meaning. This argument is opposed to the empirism for which the object has a prior meaning.

Hermeneutics argues that the knowledge act entails a previous comprehension, a cultural memory - language, theories, myths, points of view - and therefore, they draft an interpretation of the text or fact which is faced. This sketch may be reasonably adequate requiring a later analysis of the text and context. Each interpretation happens under the light of what is known and what is known may change as interpretation is being processed. The Hermeneutics considers the historical process as a principle for human being comprehension. The search for truth and understanding takes place within a tradition to which all individuals are subject and which makes understanding possible. This tradition is an aspect that determines and makes possible each and every understanding.

Thus, in phenomenology understanding means the acquisition of a way of being which appears to the subject, whereas understanding in hermeneutics considers the human being, the world, as possible symbols of interpretation. Both of these conceptions are opposed to the classical conceptions from rationalism and empirism.

Therefore, the issue of knowledge is not satisfactorily approached neither by rationalism nor empiricism, that is, the construction of reality cannot be carried out by systematic deduction neither is reality a fact that appears ready in front of the cognitive subject. Moreover, it is within the phenomenological-hermeneutic framework that one finds "the possibility for human beings to be critically placed in the knowledge context" [7].

It is also relevant to refer to the point of view of Demo [8] who contrasts the notion of construction with that of reconstruction of knowledge. In the first, reality would be caught by the perception and mental system which interprets it in a constructive way. The latter is a hermeneutic view according to which "we learn from what we have learnt, know from what is known, perceive reality within a certain previous context". Demo privileges the second notion although he considers this as an unproductive debate. This paper does not aim at probing deeper into the question as it considers the two as complementary approaches in the sense that what prevails, in both situations, is the argument in favour of a subject's autonomy through the learning process. As a result, this paper argues that the teaching/learning process may be seen as a phenomenon of construction/reconstruction of knowledge.

In this conception students play an active role in the learning process by bringing their own history, experience, initiative and autonomy. The context and the moment in which learning is developed are vital in this process in which participants interact with a new situation (a text, a theory, an experiment). In this approach knowledge is generated through the interaction between the subject and the object in a way that both subject-object and subject-world are integrated in knowledge dynamics.

THE CONSTRUCTION/RECONSTRUCTION APPROACH TO TEACHING AND LEARNING STRATEGIES APPLEID TO ENGINEERING EDUCATION

From the conception of knowledge as a construction process, Cortella [1] considers two essential elements in this process: 1) the knowledge is a historical relation which takes place in time and needs to be historically contextualised; 2) the knowledge is not an isolated relation between the world and I, but it is a result of a collective construction. In that sense, something that is true in a particular historical moment may not be in another moment (geocentric theory x heliocentric theory); something may be considered true in a particular society, but it is not in another one (tribal society x west society).

In this topic it is considered some possibilities to approach knowledge as a construction/reconstruction process which can be developed for teaching and learning strategies.

a) To realize a historical recall of knowledge.

A knowledge (i.e. a theory or a technology) may be recalled from its historical and contextual origin: the time it was created; in what conditions it was constructed; what factors favored or not its construction; what needs existed in that time; what interests were in place; what other related knowledge were available and how they contributed to that particular study.

b) To assess the context of knowledge in current time.

A certain knowledge can be assessed in terms of its current condition: which factors were considered in its current validation; why this knowledge was chosen and not another one; which societies benefited from this knowledge; what are the influences in technology, in the environment, in the social values, in peoples vision of the world; which truths arose and which were dismantled from its social application; what are the future tendencies.

c) To consider the knowledge dynamics.

Knowledge can considered within its dynamics in relation with other forms of knowledge and of its own construction. If its is managed in a static way, a certain knowledge ends up by reducing itself to rules and information, leaving the one who is learning paralyzed before the situation in which he has been put. Nowadays, the quantity of inventions created in the last 50 years is considered to be bigger than the quantity of inventions of all the rest of the history of mankind and the tendency is for this to increase even more. This is an indication that teaching and learning should be conducted in a way which prepares the student to learn how to evolve inside this dynamic and not to concentrate on the learning of immediate technical knowledge which will shortly be replaced.

d) To relate knowledge to the current paradigm.

This issue recalls Thomas Kuhn paradigms. Reference [9], quoting Rorty, makes a distinction between epistemology and hermeneutic. The epistemological thought develops itself within the current paradigms making "normal science" while the hermeneutics position is the equivalent of the contact with the new paradigm. Using physics as an example: there is the classic physics which takes into consideration the forces, the movement of particles ant the interaction between them, and there is the modern physics which studies the probability of events, energy-mass equivalence and duality wave-particle. When, at the end of the 19th century, classic physics could no longer explain in a satisfying manner certain phenomenon (like the photoelectric effect) a new way of interpretation of the physical phenomenon was made necessary, a new way for the physics to look at the world. This meant a change of paradigm in the meaning defined by T. Kuhn. Therefore, the way that a scientist sees a specific aspect of the world will be guided by the paradigm which he is working. Proponents of contrasting paradigms live in different worlds. When a scientific community acts within a paradigm it means that those scientists deal with certain theoretical suppositions, laws and techniques that try to explain the behavior of certain relevant aspects of the world until the difficulties lead them to a problem without solution in that paradigm triggering a crises. It is important to consider this paradigms issue whenever a specific knowledge is in focus.

e) The error integrated to the knowledge process.

This case is presented by Cortella [1] when taking Thomas Edison as an example. When it is said that Edison invented the light, one can infer that he discover a secret which was hidden somewhere. However, it is important to say the he carried out more than 1000 experiments which failed before he gets to the success. The error is not an external entity to the knowledge process; it is a fundamental component in this process. How many times, in engineering courses, the laboratories classes are carefully prepared to go right, that is, are planed in way to avoid that students do not face situations where the solutions are not known. It is very common to consider the error as a catastrophe and give it a punishing sense. Nevertheless, our knowledge about the world takes place in a live relation and changeable with the world itself. The error is, therefore, fully integrated to the knowledge acquisition process and it makes possible the reconstruction of knowledge.

f) To plan the course together with students.

In order to address this concern it is necessary to stress the relevance of the course planning [10]. It should be set up as a co-operative agreement aiming at fostering partnership between lecturer and students for the sake of students' success. Course planning is presented and a previous and consensual set of rules and regulations is drawn up. In this opportunity a friendly relation with the students should be demonstrated in order to build positive expectation that may build a favourable teaching/learning environment. The next step should be a questionnaire applied to the students as a way of keeping in touch with them and starting the formative assessment.

g) To start from students previous experience.

This approach considers the student-subject facing the object of knowledge. In this case the student is considered having a cultural memory which would be changed and improved during the course and must be taken into account when deciding the teaching/learning strategies. This approach supports the needs for the formative assessment components right from the beginning and throughout the course. It is important to stress that throughout this assessment procedure the relationship lecturer-subject and student-object of knowledge is exercised.

h) To design teaching and learning strategies.

During interaction between lecturer (subject) and student (object) teaching/learning strategies should be chosen from the ones described bellow [10]:

group work, supervised by the lecturer, aiming at working with students as persons, assessing students individually, motivating them to learn and developing co-operative learning while promoting a physical and affective relationship;

work on the blackboard, as a way to develop both self-reliance and the ability to solve problems by interacting with the whole group which, in turn, makes them learn how to listen, reflect and work on the error;

homework, so as to reinforce and fix the concepts and principles learned as well as to practice self-discipline, allowing students to review and formalise the acquired knowledge by giving them the opportunity to question the studied content;

lecture, the lecturer leads the group aiming at motivating them to start important topics and inviting them to exercise analysis and synthesis of a particular unit focusing their attention to the difficult points so as to promote analysis and reflection;

self-assessment, to make students reflect upon their mistakes and, as a result, develop the ability to perform critical analysis and having positive attitudes;

re-assessment, aiming at giving students the opportunity to review the topic in which they did not succeed in demonstrating the learning outcomes for a second chance summative assessment – hopefully successful;

informal conversation, with the objective of establishing a personal relationship thus enabling a closer contact between lecturer and students and therefore a demonstration of personal interests from both sides;

simulations, by using software packages.

i) To consider assessment as learning opportunity.

At the end of the learning experience lists of exercises should be done and marked. Having carried out the review and explained all the questions, the learning outcomes should be assessed through individual tests. The intention here is not to get a grade but to learn [11].

The class, immediately after the lecturer has marked the test, students receive the test in a way that they know neither the right answer nor the grade. Led by the lecturer students mark their own test and should allocate grades according to what they think is correct. During this process, and as a way to demonstrate control of the results, the lecturer poses questions to students who have failed in some topics.

After self-assessment has been carried out the tests are returned so that the lecturer can contrast the marking procedure by comparing the lecturer's own results with those produced by the students. Finally both lecturer and student decide each individual final grade for that particular test. During this process specific difficulties and mistakes if any are listed and activities planned - tailor made - for each student in particular. An extra-time, previously defined, is given for carrying out remedial activities and a new assessment is booked. By the same token, during this time student may take advantage of a software package for further practice and consolidation.

In this proposed approach, formative assessment is a lecturer decision to make sure that all students can learn at their own pace. In that sense, reassessment should take place as soon as possible. However, it is necessary to ensure that students still have the opportunity to: overcome their difficulties, demonstrate learning outcomes and succeed in getting approval and, as a result, move on to the next learning experience.

An important point to be stressed in this approach is that the possibility to eventually succeed in each test and, at the end, in the whole subject make students appreciate the subject and developed motivation. The idea should be inculcated that their learning process depends very much upon dedication and persistence, since they are given enough time and appropriate learning conditions.

At the end of the course each student should be asked to carry out a self-assessment. After that, lecturer and student together analyse the student performance in all steps, including student development, maturity, knowledge, abilities, learning outcomes achievement and self-assessment as bases for the final mark.

j) Research as knowledge tool.

This is a position advocated by Demo [8]: "research is an intrinsic component of all deep, questioning and creative learning". Research should not be analysed only as a scientific principle but must also be considered in its educational aspect – base of emancipation not only for students but also for lecturers. The Cartesian position which, points out only the certainties, makes it difficult the appearance of doubts and questionings, which are essential for the learning process. To educate through research involves questioning, doubting, breaking certainties, deconstruct patterns and then elaborating and reconstruct them. For an idea to make part in ones conscious it is necessary that it is reconstructed and elaborated by the person. In that sense it is up to the lecturer to motivate students to identify and deal with the problem rather than solving it for them.

k) The teaching/learning process is a political act.

Inside universities, in general, the importance is stressed on the technical aspect of knowledge. However, the learning process is essentially a political one. During the process of forming a professional, the technical aspect, the instrumental, the logic are carried out but, the aim of the learning process is to acquire political competence, capability of driving their own history and forge professionals able to have creativity and build their own destiny. A learning process in the political sense implies, for professionals, developing competence in order to create their own way of life, to contribute to a better society and to know how to assess and act when facing experiences. Moreover, the teaching and learning process as political act leads to the emancipation of the professional, to developing a critical consciousness and to build the citizenship. In that sense it should lead to questioning truth, imposed labels and checking meaning behind the words (speeches).

CONCLUSION

The issues above demonstrate the possibilities of dealing with knowledge in an alternative perspective. Deny to the students the understanding of the cultural, historical and social conditions of knowledge production implies to reinforce students perplexity sensation and students powerless – immobilizing them for questioning and for creativity, make them feel incapable to overcome the posed truth and, therefore, think the static world, without dynamism and with no changes possible.

The effort to change led to the practical development of an alternative pedagogical approach based on the conception that knowledge is a construction/reconstruction process that, in turn, is study centred, focused on lecturer/students commitment, error logic and continuous assessment (including formative assessment). It was demonstrated that it is possible to achieve

positive results in students' performance when learning in engineering courses by using the methodology which takes into account the principles and concepts discussed in this paper [10].

Solution for the addressed problem is a result of political attitudes and technical competence. A political commitment which provides relevant educational changes in both course and students as a result of deep transformations coming from educational conceptions.

Knowledge is not an innate feature; it is not situated in the subject pole neither in the object pole and cannot be transmitted. Within this conception the student is not a passive person who receives the knowledge and, by the same token, the lecturer is not a knowledge transmitter. Moreover, knowledge as a continuous construction/reconstruction process embraces a set of dynamic procedures which make possible relevant advances in the teaching/learning process for engineering courses.

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