A NEW INTERACTIVE PROCESS FOR ENGINEERING EDUCATION

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ABSTRACT

This paper describes a methodology to be used in different courses of the Production Engineering area. In these courses, decision-making processes are presented to future engineers and also discussed. As it is well known, these professionals will work in industrial organizations, with functions and tasks related to decision-making processes. Essentially interactive, the methodology seeks to transfer the responsibility of decisions to the student, giving him/her the lead role in the process. As a conceptual support to the proposed methodology, a group of tools of Artificial Intelligence (AI) was used, more specifically, interactive modules of an Decision Support Expert System were developed.

1. INTRODUCTION

This paper discusses a new experience in engineering education. It concerns an interactive teaching and learning process with the use of advanced techniques of Artificial Intelligence (AI) and other devices of interactive computer science.

This special type of educational process can be seen as a training model. Future engineers will use it in the companies they will work for. So, at the same time, we are introducing a new educational process and putting the students in contact with factory reality.

We have called this model "active training" because, in this case, the students we are training do not have just a passive performance, but, on the contrary, he/she acts directly in decision-making processes that are presented to him/her. The training is for students that will act in decision-making and managerial engineering processes of industrial organizations. For this reason, the experiment was carried out in courses that include Decision-making Areas, Quality Control, Economics, Management and Engineering and similar contents.

There are in technical literature some similar experiments, like the one described by [1] to the statistics area. But there are many differences when comparing these experiments with those conducted in our project.

In fact, essentially interactive, the methodology aims at creating a mechanism that makes the engineering student responsible for decisions when facing some practical problems presented to him/her, giving him/her the lead role in the process.

The conceptual support to the proposed project includes a group of tools from Artificial Intelligence (AI). We have used, more specifically, interactive modules of a Decision Support Expert System. This paper, besides describing the training model, also describes the necessary computational support for its development and the main results we have obtained.

The experiment was conducted along four years at the Federal University of Santa Catarina, in Brazil, including 320 students of Civil Engineering, Production Engineering and Electrical Engineering. The experiment can be seen as a multidisciplinary integration, since it involves several contents, a multimedia teaching tool, since it includes direct contact of the students with advanced computer science technology and also a new quality strategy in engineering education.

The main characteristics of the method is the active participation of engineering students in the teaching and learning process.

2. DECISION-MAKING PROCESSES IN THE PRODUCTION ENGINEERING

Within the context of different courses in the Production Engineering Area, emphasis has been given to the presentation and discussion of decision-making processes in which future engineers should act in an effective way, both in industrial organizations and in services. Decision-making processes are typical situations in Production Engineering, whatever model, environment or whoever is involved in the problem being studied..

Decision-making processes appear in different contexts. They can be related to the sciences of materials (decisions on stocks, for example), economic-financial procedures (such as decisions on the nature of investments), strategic planning (what market to sell to) or management (decisions involving people), among so many others.

In the most common situation, decision-making processes are taught to students from under a theoretical perspective, i.e., theoretical elements are presented. Sometimes, the teacher reports some experiences that he/she has had or lists bibliographical references where decisions on practical situations are described. In both cases, we can notice a passive attitude on the part of the students, a kind of indifference. He does not react to the issue that is being discussed.

This paper describes a project that intends to avoid this indifference and passive attitude of the students. For this purpose, a teaching-learning methodology was developed. The main characteristics of the method is to introduce decision-making processes to the students in the usual (or general) form of those processes. The task of making a decision, however, is completely transferred to the students. They will not only observe what other people have done in a given situation, but they will also play a critical role in this given situation: they will decide what to do.

This methodology is essentially interactive and seeks to transfer the responsibility of making decisions to the student. Different situations are proposed. The student cannot understand immediately the direction, the context and mainly the consequences of each decision just because there are many elements in each situation created. So he/she has to rely on his/her knowledge, experience and feeling to make each decision. The interactive approach means that the new situations proposed depend on previous decisions made by the student. According to each answer, new questions are made; according each decision, new challenges are put forward.

As a conceptual support to the project, basic tools of Artificial Intelligence were used, more specifically, Decision Support Expert Systems. For the experimental application of the project, practical situations of the courses on Quality Management, Quality Evaluation and Statistical Quality Control were selected. Different situations were introduced to the students as modules of an Expert System. The students interact with such modules selecting decisions according to various practical cases.

The project uses a recent methodology with advanced computational support and new technological structure. But the main point is the basic characteristic of the methodology: It changes the student - from a mere spectator to an effective decision agent of real practical processes. It is worth pointing out that these processes are part of the contents included in different courses of the Production Engineering area.

3. DECISION PROCESSES IN STUDENTS' EVOLUTION

Frequent evaluations of Engineering courses have shown that students, during the course, do not use critical sense when they are faced with several problems or uncommon situations for which decisions are required.

Such lack of critical sense has been detected by companies that have hired young engineers, who have just left the universities. Our research has concluded that the companies think the new engineers stick to and do not seem to go beyond the repetition of formulas and procedures applied in identical situations, they try to get similarity between the situation they are seeing now and some situation they have seen during the course. It has been observed that new engineers work with analogies between the real situation they are dealing with and a set of references - the contents of books, classes or experiences of teachers. If no analogy is found, they try, at least, to establish some similarity, without putting in doubt the validity of the procedure.

The main evidence of this deficiency is observed, in practice, through the passive acceptance of absurd results of calculations made in classes or in the analyses of practical problems. Sometimes, an answer that has no chance to be real is considered as absolutely common and normal by the students.

The lack of a clear notion of values and of their magnitude is a typical symptom of the habit that the students acquire in the university: they get used only to applying formulas and to repeating procedures, without questioning them.

The present paper considers a simple hypothesis: this lack of critical sense on the part of the students is frequently found in courses that involve decision-making processes; it occurs because we are using a wrong way to approach those processes.

Practical observation shows that in many syllabi the situations are presented to the students in a descriptive way. Teachers transfer to the students decisions they have made or others have made; they describe what formulas have been applied; where certain tools or strategies have been adopted. The student, in a passive way, just observes what happened. He receives information and tries to memorize it. As a consequence of this static attitude, without any kind of questions, the students stop developing a critical sense regarding the problematic situations and the way they were solved in the past.

To minimize this problem, we propose a new method to present decision-making processes in Engineering courses. We call it an interactive method, intensively participative, because we transfer to students the task of deciding what should be done at each step of the process. As I work in the area of Production Engineering, I decided to adopt myself the practice in the course of Quality Management. For space reasons, just one of the practical cases introduced to the students is described here.

It should be clear that this new point of view about decision-making processes is not enough to make them attractive, to bring motivation to the question. For this reason, I looked for tools and strategies that made possible to give to the students the "decision power" in a simple, practical and, above all, attractive way. I strongly believe that Artificial Intelligence tools make possible to achieve this goal. Hence the idea of using Expert Systems in this project.

4. EXPERT SYSTEM FOR THE TEACHING-LEARNING PROCESS

Expert Systems (ES) are computational programs that try to solve problems in specific fields of knowledge. Because of the concepts Expert Systems have and because of the diversity and relevance of the applications known, ES have been used in a great number of practical situations. It is already considerable the number of texts in this area published in Brazil, as, for example, [3], [10], [2], [4], [12] and [7]. Classic texts, such as [11], [9], [5] and [8] are also available.

There are many reasons to justify the use of the Expert Systems approach to the didactic experiment of proposing students' integration to the decision-making processes presented in a number of courses. Several good results have shown that this approach is well suited to Production Engineering courses. In fact, many problems presented in courses such as Quality Management involve decisions that are presented to human beings in certain situations. Since they do not have a specific mechanism to evaluate in a measurable basis the situation that requires a decision, the decision agents try to identify particularities that allow them to confront what they see with some pattern or some known standard. A classical situation where this specific methodology of analysis is used is quality inspection, based on the quality inspector's feeling.

In many decisions of the Quality Management area, and, in particular, in most of the decisions of Quality Evaluation in industrial processes, products and services (one of the most important elements of the course), a computer device, to be useful for the decision process, needs to work in a way completely similar to the way of acting of the own decision agent. So the fitness of techniques of Artificial Intelligence to this case seem evident.

Another useful didactic aspect refers to the analysis of the efficiency in the treatment of some problems (Expert Systems provide high efficiency in decision processes). Because of the objectivity required for decisions in industry and also because of the safety necessary to the whole process, it is clear that the use of Artificial Intelligence techniques can be extremely useful in obtaining a more reliable information concerning the decision involved, in addition to being useful in making possible to obtain it in a faster way. This aspect can pay off the costs that the structure of the system may bring.

On the other hand, the decision of an Expert System is monitored continually by the user. At this point, the student begins to play an active part, taking the responsibility for decisions that the System is making, evaluating them and correcting them if necessary.

Another analysis can justify better the use of Expert Systems in this project. Since this approach causes intense interaction between the student and the decision process, it tends to generate a critical behavior for each decision taking and its possible consequences. We should consider also that some authors, when studying the concepts of Artificial Intelligence (AI) and its more usual tools, emphasize that AI is better suited to situations where the solution to the problem strongly depends on the adaptation of techniques and methodologies to the environment being considered in a given occasion. We can identify, for instance, the analysis of [11], for the case of Expert Systems. This analysis is adequate for the objectives of the present project.

It should be noted initially that, in order to be solved, the decision-making problems related to Quality Management (the same can be noticed in other Production Engineering courses) require computational techniques whose characteristics are not found in usual programs. Indeed, decision-making processes do need a methodology that allows us: (1) to give flexibility to the computer program we are using. So the student will not feel like a robot, repeating experiences of other decision agents. He must know that he will generate his own solutions; (2) to work with situations of uncertainty associated to important stages of the process. The student should have in mind that he/she is not facing a problem with ready-made solutions. So he/she will not have the impression that he/she is doubling his/her efforts without contributing to the improvement of the problem; (3) to introduce new knowledge in the problem wherever it is convenient, according to the development of the decision-making process. This is fundamental - otherwise, the student could not apply the methodology in different practical situations; (4) to separate the knowledge itself from the structure that will manage and control the Expert System. This will be important for the student to apply knowledge he has acquired without needing to become an expert in Artificial Intelligence; (5) to obtain satisfactory results - but not necessarily optimal - to the process. It is important that the student have in mind that we are not demanding from him/her the impossible - but just his/her participation to attain the best results according to his/her knowledge and aptitude concerning the topic in question (and not ours).

All these elements are usually dealt with by the Artificial Intelligence concepts and strategies. They show that the AI techniques are much more adapted to the problem we are tackling here than any other traditional approaches. There are other important points to consider that have justified the use of AI techniques in this project. We ought to highlight yet the following: (a) the knowledge required to solve the problems presented to the students in Production Engineering courses is available and structured with a reasonable organization degree. So we have less interest in generating new knowledge than we do in generating new behaviors (even if dealing with concepts and tools already known); (b) the main purpose of the project is the correct application of certain tools to specific practical situations. Then the decision to be made is the critical point. We present it to the students as a challenge; (c) we do not ask the students to create new theory concerning the knowledge. The evaluation of the methodology should be concentrated in measuring how correct he/she acts when applying some technology to practical problems. And how this behavior helps him/her to create his/her own critical sense. To make these points clear to the students is of great importance, otherwise, they may feel intimidated and give up on the process - with fear that we are asking them more than they can actually give.

5. PRACTICAL USE OF THE METHODOLOGY

A practical situation where the methodology has been applied is described now. An important problem in the Quality Management course involves a typical practical decision. It concerns the quality evaluation in production processes in industrial environments. The main question here is to define the best option from two types of inspection: the inspection developed by attributes or the inspection done by variables. This decision is also critical for other courses in the Production Engineering area, such as the following: the analysis about control charts, for instance, in courses on Statistical Quality Control; the study about abilities for some kind of human actions, for instance, in Human Resources courses; the decision on the best sampling plan to be used to evaluate specific products or services, in Quality Evaluation courses; the analysis of methods and principles of training, in Human Performance courses; decisions on what equipment to buy, in Strategic Planning and the definition of intermediate stages of the productive process, in Production Planning and Control.

This kind of decision - attribute or variables - was considered as adapted for the application of the methodology. In order to develop it, a module was structured of the Decision Support Expert System that determines the best choice in the case of the decision between quality evaluation by attributes and by variables. It should be clear that this is only one of the several modules of the whole System.

The conceptual basis of the module involves important definitions for quality evaluation, such as quality characteristics [6], and the basic contribution that the evaluation process has to the quality concept. It is important to emphasize that, usually, the evaluation of all the quality characteristics of a product is unfeasible, mainly those of greater complexity. Thus, the control of the quality characteristics tends to be limited to the most important ones. It is obvious that the evaluation concentrates also in quality characteristics that request effective control.

During the preliminary discussion of the issue it is shown that there are two basic forms of applying the quality control to a product, considering the evaluation of its quality characteristic: the control by attributes and the control by variables.

The characteristics of each control type are then discussed in general terms. Information about the use of each control is given using practical examples (this introduction with the use of real situations is critical for the whole process). Thus, for example, it is mentioned that the control by attributes is always done in a discreet scale, and, in general, binomial, where two classifications just define all the variation of quality characteristics. Other presented facts are the following ones: (a) most of the time, the classification by attributes has a subjective basis for the decision making. That is, in many cases, the inspection of the quality characteristics strongly depends on whom executes it (Example presented: analysis of color tone for tiles); (b) the control by attributes is made, essentially, with the use of the five senses: touch, smell, taste, hearing and vision - with the following examples: (1) control of moisture in products such as coal (we “feel” the product with the hands); (2) detection of the presence of certain substances in gases or liquids, done by the control of the smell of the product; (3) control of the flavor of drinks, or food, done by experienced tasters; (4) classification of sounds, in pleasant or unpleasant, for bells or musical instruments; and (5)observation of color tones of tiles or floors; (c) the inspection by attributes does not determine the intensity of a defect, being limited to diagnose its presence or absence (Example presented: a lamp - that works or not).

After discussing these points, we go on to the control analysis by variables, with the characterization of several situations where this kind of control is used. Practical examples of evaluation by variables are presented and also discussed.

The next point in the methodology project is to approach an important subject: which evaluation type to use - attributes or variables. In fact, for the characteristics of each control methodology, for some quality characteristics the control by variables is the most suitable; for others, the control by attributes fits better. Additionally, we could observe that there are quality characteristics that require a certain control type because of their own nature or for simple convenience reasons. Thus, the selection of the control type to be adopted depends both on the quality characteristic itself and on the particularities of the method.

The several analyses considered for the choice between the two kinds of control are then described. The analyses follow the steps below: (1) The importance of correctly selecting the inspection method is the first point to study; (2) As a basis of evaluation of the product quality, a misunderstanding in the selection of the control type to use means the establishment of an incorrect quality level of the product; (3) The methods and techniques of the Statistical Control of Quality, to processes or to products, are specific for each case (attributes or variables); (4) The inspection by attributes presents great theoretical and practical differences when compared with the inspection by variables.

Most of the differences should be considered in terms of costs when a kind of control is used mistakenly. Differences in costs are a consequence of the fact that we may be executing an expensive control to obtain information that another cheaper type of control would provide in the same way. There are also serious consequences because we are making critical decisions based on imprecise information.

Finally, from the point of view of the methodology itself of each control type, in general, several practical observations are shown. So far, the student has listened, attentively or not, to what has been shown. At this moment, the student gets to know the following: having in mind the specific particularities observed for each kind of control, the next thing to do is to detect the need of structuring a module of the Decision Support Expert System that makes possible to determine which is the best option in a certain situation, when it becomes necessary to define the most suitable form to evaluate the quality of a product from its quality characteristics.

This is the objective of the present module: to confront the evaluation of the quality made by attributes for a certain situation being studied with that made by variables.

Then the module is presented. It is an *based on rules* Expert System, with the following specifications: (1) *Number of Rules*: 93. (2) *Number of Qualifiers*: 34. The System can list all the qualifiers, as well as the rules where they are being used. (3) *Choices*: 2 (attributes or variables). The system can show all the rules the choices were used in. In this case, the choices appear in all the rules used for making the decision. (4) *Decision of the System*: Evaluation by attributes or by variables. (5) *Scale of Values*: Values between 0 and 10. The adaptation of the option made is characterized by the establishment of values close to 10 to the choice made; the inadequacy is characterized by values close to zero associated to the choice. (6) *Use of rules*: All possible rules are used in the derivation of data for the selection of the most appropriate choice. The system does not show the rules when they are being used in the execution of the program. The user can alter this option, if so he/she wishes.

The System is presented as an interactive process, on a microcomputer screen (486 or faster). The basis of the system is the software KAPPA. The user (in the case, the student) will work with the system selecting options that each qualifier presents to him/her.

Sixteen computers of the Teaching Laboratory of the Department of Production and Systems Engineering at the Federal University of Santa Catarina were used. First of all, two students are assigned per computer. Secondly, each computer is used by only one student in the next modules.

As an example of qualifier presented to the user, consider the following:

Give an answer to the question below using one of the following procedures:
click on the text, with the mouse or write the number of the option in the space.

The binomial classification of defects is: (1) enough; (2) insufficient; (3) it cannot be used in this case.

write here your answer (........)

As an example of a rule used by the Expert System, consider the following:

Rule 17: IF *the information on the defect should be general,* THEN
Evaluation by attributes - probability: 8/10
Evaluation by variables - probability: 2/10.
References: [6].

Note: If the situation does not require detailed data, precise inspections may not be necessary. Detailed information is always necessary when the inspection should be complete, involving all the measurable elements of the item.

Most of the rules have bibliographical references. They provide conceptual support to the rules. Some rules also have explanatory notes concerning their formulation or concepts they contain .

The module is made up of six basic areas. These areas involve relative analyses about the nature of the defects, the results of the inspection, the quality characteristics, the inspection methodology, the inspectors that will work for this kind of evaluation and the productive process as a whole.

In general lines, each area involves the following aspects, among others: (a) As regards the *nature of the defects*: Classification of the defects; occurrence intensity; characterization of the occurrence; information level on the defect (precision, generality, reliability and wideness); frequency of defect occurrence; occasional action of a defect on others. (b) As regards the *results of the inspection*: Forms of expression of the evaluation results; scales for result representation; forms of obtaining the results (how the results were obtained). (c) As regards the *quality characteristics* to control: Quality characteristics to control; feasibility of the characteristic for the evaluation; nature of the characteristic and its importance. (d) As regards the *inspection methodology*: Inspection costs; inspection resources; place of inspection; scope of the results of evaluation decisions; analysis of defect causes; emphasis and objectives of the inspection; sensitivity level of evaluation; forms of carrying out the inspection. (e) As regards the *inspectors*: Inspectors' qualification; inspectors' formation; characteristics of the inspectors' action on the evaluation process. (f) As regards the *productive process*: Consequences of the results of the inspection on the productive process; production levels.

6. RESULTS, CONCLUSIONS ARE AND RECOMMENDATIONS

The Expert System described was tested in twelve specific situations, involving 440 students. In all the contexts, the Expert System showed appropriateness to the cases studied, having in mind the objectives of this project.

Being a module of a decision support system, the Expert System was tested initially in practical situations for analysis of its consistency. As an example of its application, the system was used in specific cases where, according to some characteristics, a typical result of the process was expected. The previously defined decision was the same made by the system in all the tests. So the application of the system was done with real data taken from productive processes studied.

Another approach that can be used refers to the evaluation of the results of successive applications of the modules of the system. Experimental use shows that their decisions changed according to well defined factors. If the results changed, then it means that some elements also changed. So these elements should be followed up, because they indicate situations that require preventive control in most cases. The management of the changes of the results gives the teacher a method to evaluate the students - if the results change, the decision has been also changed. By evaluating the results, we can assess the decisions. The Expert System is like a mirror – it shows exactly what the students have done.

Tests in the operation of the modules showed that the sensitivity of the system is high, and its results can be altered with small changes in the decisions of the students when some qualifiers are presented to them.

Since the consistency of the system was guaranteed, it was possible to evaluate the didactic experience itself. Important aspects of the experimental applications were considered satisfactory as the following: (1) The students did not feel bored or tired when supplying the answers and there was not an marked disagreement in relation to the answers of the system (the system tends to make decisions similar to those of the students); (2) The system was considered to be practical and it is coherent with the students' expectations - there was not discrepancy in the reasoning that the system and the students had along the analysis of the subject, when searching for a decision; (3) The system seemed to be structured in a consistent and well formulated theoretical basis to the students. This basis was transparent to them.

We asked the students about their confidence in the modules. 91.5% of the students answered that they found it reliable. In a scale from 0 to 10, their grades ranged from 7.2 to 9.8, with an average of 8.95. The main satisfaction reason was due to the chance of participating in its decisions. In general, they considered it a high motivation factor, and this was evident in the process. When asked to foresee the answers of the system, the students developed a critical sense about the problem and trained to get the right solution to proposed problem, according to some characteristics of each situation considered, before the system gives its decision. The answers were correct in 86% of the situations.

From the results of the case studied, we have considered the Expert System to be appropriate for the didactic problem in question. In terms of students' participation in decision-making processes, the results obtained here allowed us to verify the validity of the proposal of this paper. This project, however, shall be improved during its real application. It means that, instead of bringing a definitive result, the project reveals the beginning of a research line.

Finally, we would like to suggest the application of the system to other situations and the development of more interactive ways in relation to the user as a next step. Since this module is still being tested, we must continually evaluate its use.

Another recommendation to be done regards the development of an interactive evaluation model of the student's answers. This model, based on Fuzzy Sets, evaluates the students' answers and gives a grade to the decisions they make. This fuzzy model makes possible to detect weaknesses (that contributed for the taking of mistaken decisions) and potentialities (that determined the selection of correct options) of the decision agents (the students). Still in an experimental phase, the model should evaluate the progress of the student according to the decision process under study.

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