INTERNATIONAL JOURNAL OF EDUCATION AND INFORMATION TECHNOLOGIES
Issue 2, Volume 2, 2008

Active and Interactive Learning Processes: A General Model using Expert Systems Approach

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Abstract - This paper shows how Expert Systems support can be used in active and interactive learning processes. "Active" means that students really take part and contribute to the process. "Interactive" is in the sense they create a collaborative and dynamic set of mechanisms to stimulate their own learning. Initially the interactive teaching processes are shown. The basic presupposition of this process is that there is much efficiency in learning if the student adopts an active, energetic posture during information transmission. The hardware mechanisms for interactive teaching are then described. As the software devices for the model, a set of expert systems is considered. They involve general areas of Engineering Courses, like manufacturing processes, quality management and supply areas. Finally, the evaluation of the whole experiment is discussed.

***Key-words*:** Active learning; interactive learning-teaching process; Expert Systems.

I. Introduction

Engineering teaching should keep up with the technological development pace that characterizes the evolution of Engineering as a whole. Thus, those postures, aiming at the maintenance of dated teaching standards by showing their advantages only due to the fact that they are characteristic of the Engineering teaching-learning model, are unacceptable today. In this sense, two positions are harmful: to ignore usual teaching methods by the simple fact that they are not new ones or, on the other hand, to stick to traditional processes without considering the possibility of taking advantage of developed mechanisms of software or hardware.

This study starts off from the hypothesis that we should not disregard usual teaching methods, but there is no reason to refrain from investing in new processes, having mainly in view the recent progresses in the technological area. This is not to say, however, that such elements should be incorporated to teaching due to the fact that they are innovative, updated or modern; rather, what we intend to do is to take advantage from them.

These aspects are particularly noticeable in the scope of dynamic and communicative teaching methods, that we call interactive teaching, which is a relatively recent process to motivate learning so as to develop critical postures on future engineers concerning the contents they are being taught.

Manuscript received April 30, 2008: Revised version received September 4, 2008.
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II. Interactive Teaching Systems

The idea inspiring interactive teaching processes is quite simple. The basic presupposition we are starting from is that there is much efficiency in learning if the student adopts an active posture during information transmission. If it cannot be considered to be a new proposition in the teaching-learning relation, it can be said to be rather infrequently applied in the day-by-day practice of universities. As a matter of fact, our teachers still hold to obsolete methods of unilateral information transmission, a source-receiver oriented process, always from teacher to student. According to this model, the source emanates knowledge and student is the receptacle who absorbs it. It van be seen that it is an active and adaptive method. And many authors in Engineering Education have pointed out the importance of active learning processes, mainly in an adaptive way (see, for instance, [1]).

The supremacy of this method over other alternatives is seemingly attributed to two primordial factors. Firstly, this is a method that demands little effort from teachers. No more creative methods for the presentation of concepts, strategies and formulas are required. It is not even necessary that classes prepared for the second term of 2007 be updated to be taught in the first term of 2008. But, invest in innovation is always desirable. It is important to point out a rather common posture: the use of inadequate payment levels or poor motivation process as a justification to the lack of class preparation. Students, however, are not to blame and, therefore, cannot be penalized.

The second factor to be considered is a consequence of the first one and has to do with the commodity of teachers themselves. This teaching process, via transmission from who holds knowledge, is adapted to teachers. A method is thus structured according to which is suitable to those who are teaching, but not to those ones who are learning.

Elementary principles of Total Quality Management (TQM) can be applied here: every action must be aimed at the client. If society is the external client of our schools, students are the immediate and internal clients. Therefore, the teaching process ought to be adapted to them and not to those who are teaching. Hence, the notion of adaptive teaching characterizes the interactive process herein described. Nevertheless, in the case proposed by this study, it is necessary that teaching process be adapted to students and not to teachers, unlike what happens with traditional postures, harmful to the new teaching-learning relation.

III. Hardware Mechanisms for Interactive Teaching

In a teaching process, adapted to students, it is purposed that they find out the facts starting from basic clues given to them. Thus, the student/teacher interface begins to be critical, inasmuch, as this is the only way teacher can realize how students are developing the questions under discussion.

The student/teacher interface was the main element characterizing the Distance Education process adopted by the Production and System Engineering (PSE) Department, in Federal University of Santa Catarina (FUSC), and in Distance Education Laboratory some years ago. It was a pioneer project in Brazil and it took interactive teaching systems as its element of differentiation in relation to the other Distance Education models, adopted in the country (and even abroad: before its implementation, professors from the PSE Department had the opportunity to get to know Distance Education systems from France, The United States, and Japan).

In that case, the interface found its critical process in hardware area. How can a teacher who is in Florianópolis interact with a student who is in Manaus (3,500 km away)? This problem was solved with the use of a specific hardware, which had involved equipment of transmission and reception of simultaneous signs. Special TV sets, installed in remote rooms (where the students were), show the image of the teacher, who was in a studio located in Florianópolis, in the PSE building.

The usual hardware support made possible two basic modes to implement Distance Education mechanisms by means of interactive processes: videoconferencing and teleconferencing. The Distance Education model, adopted then, consisted of creation, production and satellite broadcasting of video classes received directly by the users, whether by means of direct capturing from satellite dishes, or by means of open TV program windows (broadcast). In order to lead the learning process, texts are written with formal contents related to each video-class generated and received. Evaluation is also developed, so that students can check their learning progress. The interactive process is complemented with periodic in-person actions, where the teachers carry out an in locus checking of the teaching/learning process.

With videoconferencing system, the Distance Education Program makes possible to hold formal courses through the on-line process, integrating FUSC live with many other universities. In this case, there is a process that makes possible not only student/teacher interaction, but also teacher/teacher and student/student interaction. This system can be extended to companies and governmental institutions in such way that trainees receive technical information without traveling to Florianópolis, or wherever teachers live.

Teleconferencing is an interactive process, which serves the continued education purposes without being restricted to formal courses. The target audience includes people with a consolidated technical background and for whom interaction with teachers is intended to complement their knowledge.

So, satellite broadcasting of the lecturers is generated in order to improve the interaction among the participants through telephone calls or internet (like chats). Broadcasting can take place by means of open or coded signal for reception by satellite dishes or open signal broadcasting stations.

The interactive system applied in the Distance Education System to the Distance Learning involves mainly communication by internet. This method allows students surfing on the program activities. An example is the software set named as Quality Management Games, in which there are simulations of decisions about the quality areas operation (Statistical Quality Control or QFD) in manufacturing or services companies and the system reacts by evaluating the decisions taken on simulated situations, but with a high probability of occurrence in practice.

The whole Distance Learning program is thus conducted according to interactive teaching. Its operational feasibility, however, depended on availability of hardware equipment, whose cost is not always feasible to engineering schools. Hence, several efforts have been done to build up affordable mechanisms. So, through the use of computer equipment, accessible at universities, interactive software sets are employed, which play a major role in the teaching modes.

The distance learning has considered as a succeeded method in several methods, as the well known e-learning form (see the experience related in Italian universities, for instance [2]).

IV. Software Mechanisms for Interactive Teaching

In order to minimize operational costs, without losing interactive characteristics, investments have been concentrated in developing software sets with easy download, friendly use and reasonably priced in terms of operation. The idea is to use computational resources already available at teaching institutions. It is made in the same way of some traditional e-learning programs [3].

It must be pointed out that traditional software sets usually do not meet the characteristics of interactive teaching systems. In fact, conventional software sets do not adapt themselves to students’ specific situations or peculiar characteristics of subjects to be taught. In other words, these software sets are not adaptive. Additionally, the most used ones for statistics of physics problems, for example, preclude (sometimes completely exclude) user’s participation in the problem-solving process. It means: these software sets are not interactive.

The present study considers the hypothesis that the Information Technology Area can minimize several deficiencies of this situation (cost, investment levels, interactivity, student inclusion in problem solution, friendly operation) is Artificial Intelligence (AI) and, in particular, what we know as Expert Systems (ES).

The concept of AI to be used here is supported by one already studied by Rich and Knight [4], who discussed how close to human tasks computers should perform their own tasks. This idea is present in several classic definitions [5]. Luger and Stubblefield [6] also discussed how AI has studied structures and strategies to solve this complex problem. Russell and Norvig [7] have presented the modern approach to

AI. They showed the importance of the basic AI concept: it is the area of Computer Science related to designing intelligent computer systems. The main characteristic of these systems is associated with intelligence in human beings, such as understanding a language, learning, reasoning, problem solving, etc. Dean and Aloimonos [8] showed that both - theory and practice in AI – use human brain as its basic model. Certainly, the logical approach of Computational Intelligence has the same root [9]. Another set of references can be seen with the same view ([10], [11], [12], [13], [14] and [15]). In reference 14, for instance, it can be seen a model for university timetabling using evolutionary computation.

There are a lot of concepts and techniques that develop the same principles of AI. Some examples can be seen in [16]. In this paper, a multi-agent system is described. This system is "capable of achieving its goals under conditions of uncertainty and which exhibits emergent intelligent behavior such as adaptation, learning and co-evolution with their environment" (typical AI actions). In that paper, the intelligence of the scheduler emerges from the horizontal and vertical interaction of its constituent agents balancing their individual and group interests.

The classical concepts of AI seem to be particularly useful when we relate AI with Production Engineering, the basic area where this project is being developed in its two modes – software and hardware dimensions. In fact, as it is its primary vocation; Production Engineering deals with the human element in a productive process. Thus, there are several areas of mutual interest in both sciences. The development of intelligent programs is directly associated to the computer procedure since it is programmed to act out as the operator's behavior on production line. Therefore, when structuring such a procedure, we seek to study human behavior in the productive process and transfer the way of acting adopted by people to a set of computer programs.

This affinity generates many areas for the application of AI to Production Engineering, the main area of the Distance Learning project we are dealing with. Adiga and Li [17] list the following as the main ones: manufacturing processes, robotics (artificial sight, for example), factory planning, product design, human and organizational factors, man-machine communication and managerial decision support.

Another concept of AI, cited by Winston [18], is useful to demonstrate how this science fits within the interactive teaching project. According to this author, AI is the computer science area that connects specific situations to actions based on human behavior. The author's idea is to structure computer programs whose development is processed very similar to the human beings in the same situation, when trying to find a solution to a given problem.

This concept allows an interesting interpretation. When working on specific problems in the same way as a human being would, it is possible to identify an affinity between user and computer program which would allows a mutual cooperation to take place. Undoubtedly, this facilitates the learning process, since the students have, at hand, a computational device which acts out according to a methodology similar to their own. It is clear that this similarity brings significant advantages to problem solving processes, mostly in terms of a better efficiency in understanding contents and perceiving techniques and strategies. An example of structures using AI concepts and techniques is the ES.

Expert Systems are software programmed to solve problems in specific knowledge areas. Their main characteristic is a knowledge basis related to the restricted domain where the problem is found. ES have been used to solve several kinds of problems and have been applied to a variety of distinct areas. According to Waterman [19], the most common application categories are: interpretation of situations observed; prediction of consequences; diagnoses; product design under certain circumstances; monitoring of systems; medicine prescription to specific disorders; damage repair of certain structures and behavior control of certain systems.

Many of interesting applications of ES, discussed here, can be seen in several references: [20]: human actions; [21]: Programming in Turbo C; [22] and [23]: Engineering; [24]: Mechanical Design; [25]: Library and Information Services; [26]: Business Applications; [27]: Power systems. Expert Systems are particularly useful for the Interactive Teaching process, insofar as they induce students to find out facts that lead to a given solution: the system substitutes the teacher by inducing the student to arrive at a certain solution to the problem based on their own means.

The proposal of Interactive teaching has specific characteristics – always in the active and interactive ways. It can be seen, for instance, in the evaluation process, that can be made on line ([28], [29]).

What can be seen at first is that there is a situation presented to students, which requires that they make a decision. Since they do not have a given piece of available information, which in traditional methods would have been passed on to them automatically, they seek to identify in the situation under study characteristics that make possible to contrast what they need to know with the knowledge they already have. This is a context that drives students to develop specific analytical methodologies, based on their own experiences, thereby creating a learning environment in trial-and-error schemes. Learning has the effective participation of the students themselves.

With the same importance of the method, the choice of the topics to the project was made carefully. So we decided to focus in three main application areas.

V. A First Case of Practical Application: Manufacturing Process.

In this first case we consider a typical example of manufacturing process. And it is possible to see how interactive teaching can be developed with the use of ES. This case involves a subject which is common not only to the Production Engineering course, but to all Engineering courses.

It is the analysis to determine the most adequate choice in the case of a decision between implementing manufacturing processes by conventional means, with the use of human resources or making use of automatic devices, i.e., developing actions related to the case in study by using special mechanisms and procedures, whether via software or hardware. Quality inspection was the chosen area to analyses.

For this situation, an ES was developed and applied to make the study of the inspections procedures carried out along an industrial line, checking if, at specific points, the quality inspection should be conducted by inspectors or by some computerized equipment.

A group of students of Engineering courses was invited to make a decision about some inspection process applied to a manufacturing work station: (1) to use automatic devices or (2) to keep the inspection procedure in a manual, visual or tactile way (attribute inspection) carried out by people (trained inspectors). The decision must be based on data supplied to students (decision agents). To take a decision, the students will use a simple ES. So, the decision (automatic or manual inspection) construction will require the students' step-by-step participation, by answering questions posed to them. The ES presents to them a lot of preliminary information: the concept of quality inspection; the ways of carrying it out and its importance for quality as a whole; the role of inspection in the diagnosis of products and processes in terms of the level of quality they bear; the usual forms of inspection and their basic agents. Finally, the problem is shown - What is more suitable: the situation where inspection is made by human operators or inspection that uses automatic devices? In the last case, the system provides the students information on facts such as:

- The decision between keeping manual inspection, i.e., carried out by inspectors in the traditional way, or implementing automatic inspection devices should take into consideration the nature of the inspection, the productive process, the decision-making process itself and even the inspectors who act out on the quality evaluation process.
- Manual inspection, if compared to automatic inspection, can be seen as an easier and quicker adaptation, inasmuch, as it makes use of human beings' versatility. Unlike, automatic inspection, which focuses on a specific aspect of quality, manual inspection involves a comprehensive judgment. Of course, automatic inspection is not submitted to restrictions of manual inspection, such as fatigue, monotony, repeated images leading to tiredness and confusion, and, lastly, psychological and physical effects on inspectors.
- If we consider advantages and restrictions to each type of inspection, a higher adequacy of one in relation to the other is detected for a given situation. Hence, it is important to explain the investments in the study of particularities of each inspection according to specific situations where it occurs. On the other hand, it is appropriate to consider the practical experience acquired through the use of each inspection. Such information can be fundamental to determine effective characteristics of each evaluation and its possible adequacy to the case in study.
- The use of one from the two inspection types can still be influenced by circumstantial situations the process goes through. Thus, for example, if inspection of the whole lot, as a common practice, has been associated with inspectors' tiredness, monotony and tediousness, there is an indication of the opportunity to introduce automatic inspection. On the other hand, a strong market retraction, determining significant investment curtailments, can compromise the employment of automatic inspection, almost always carried out by equipment of reasonable costs. The urgent need of standardizing quality evaluation to attend to specific clients or market sectors can determine the necessity of automatic inspection adoption. The same is true if production peaks require a faster and more efficient inspection processing, or with emergency alterations of the working environment, which can generate hostile conditions to the development of a more accurate evaluation model.
- Certain situations of factory must be considered. Thus, for cases where quality standards are defined, automatic inspection has a higher adequacy level than for cases where quality standards are intuitive, subjective or they simply have not been defined. Likewise, if quality evaluation emphasizes visual inspection for cases where almost imperceptible cracks or spots are relevant for quality evaluation, then automatic inspection seems to be preferable to the use of inspectors. Here, machine visual perception is more accurate than human visual perception and it is desirable to make use of such detail perception and accuracy.

Additionally, the system reports that usual situations of manufacturing process must be equally relevant in a decision making. Some examples shown to the students to illustrate specific situations were: production lines that generate large lots, whose inspection would take a long time and many resources; products whose evaluation criteria almost never change; inspections requiring a high degree of concentration and effort (whether physical or mental) from inspectors; extremely repetitive and tiring decision-making activities, but which are always relevant and required.

The ES, herein described, is based on rules, with the following specifications: (1) Number of Rules: 81; (2) Number of Qualifiers: 28. The system can list all the qualifiers, as well as the rules where they are being used. (3) Choices: two options. The system can show all the rules in which choices were used. In this case, the choices appear in all the rules used for making the decision; (4) System's Decision: Automatic or Manual Inspection; (5) Scale of Values: Round values ranging from 0 to 10. Adequacy of the selected choice becomes clear when values lie close to 10; inadequacy is characterized by values close to zero; (6) Use of Rules: every rule is used to derive data for selecting the most appropriate choice. The system can (or not) show the rules being used (it depends on the student's choice); (7) Example of Rule: IF: the process tends to be rather repetitive, THEN: Automatic Inspection: Probability: 8/10; Manual Inspection: Probability; 2/10 (Rule 46); Example of Qualifier: the process tends to generate (1) large production lots; (2) lots of a reasonable size when compared with the other processes in the factory; (3) small production lots (Qualifier 19). Most of the rules have bibliographical references providing them with a conceptual background. Some of the rules also have explanatory notes as to their formulation of concepts therein contained.

When applied to some practical situations during classes of disciplines of Engineering Courses, the system proved adequate to interactive and participative teaching and received a positive evaluation on the part of both teachers and student.

In the first case, a comparative process was used (pre-test and post-test) with the matching technique. Results were of 0.85 (approximately 85% of correct responses or positive evolution). The students considered this teaching technique to be more productive and appealing than the traditional ones (an average of 79% of responses in this sense).

VI. A Second Case of Practical Application: Quality Management.

Another example of how interactive teaching can be developed with the use of ES involves a subject, which is common not only to the Production Engineering course, but also to all Engineering courses. Here, the application comes from the Quality Management area.

A practical situation where the methodology has been applied is described and presented to the students. An important problem in industrial process management involves a typical practical decision.

The student has to define how to evaluate the process and to determine the best option from two types of inspection: the inspection developed by attributes or the inspection done by variables.

This kind of decision - attributes or variables - was considered as adapted for the application of the learning 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. It demands a student's general view of the problem.

The conceptual basis of the module involves important definitions for quality evaluation, such as quality characteristics [30], and the contribution that the evaluation process has to quality. 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 learning 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 facts presented are discussed. After discussing these points, the control analysis by variables must be done, 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 method, for some quality characteristics the control by variables is the most suitable; for others, the control by attributes fits better. Additionally, it could be observed 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 four steps:

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); and
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 still in terms of costs when a kind of control is used mistakenly. Differences in costs are a consequence of the fact that it 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 critical decisions are made 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 to adopt 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 a based on rule Expert System, with the following specifications: The system has 144 rules and 54 qualifiers. The System can list all the qualifiers, as well as the rules where they are being used. There are two choices: 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. The decision of the system is: Evaluation by attributes or by variables. The system uses a scale of values between 0 and 10. The adaptation of the option made is made evident 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. 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 student can alter this option, if so he/she wishes. The System is presented as an interactive process, on a microcomputer screen .The basis of the system is well-known ES software. The user (in the case, the student) will work with the system selecting options that each qualifier presents to him/her. As an example of qualifier presented to the student, 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 measurable classification of defects:

(1) is necessary.
(2) is desired;
(3) 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 exact, precise
THEN Evaluation by attributes - probability: 2/10; Evaluation by variables - probability: 8/10.

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:

1. 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.
2. As regards the *results of the inspection*: Forms of expression of the evaluation results; scales for the result representation; forms of obtaining the results. (How the results were obtained).
3. 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.
4. As regards the *inspection methodology*: Inspection costs and 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.
5. As regards the *inspectors*: Inspectors' qualification; inspectors' formation; characteristics of the inspectors' action on the evaluation process.
6. As regards the *productive process*: Consequences of the results of the inspection on the productive process and production levels.

VII. A Third Case of Practical Application: Suppliers Management.

This third case concerns the supply management. The students are informed that the structure of the raw material reception area in a factory is usually divided into two areas. In the first one, all of the raw material arriving at the factory undergoes a preliminary analysis called *Inspection Control*.

Here one decides whether the raw material ought to be inspected or not. Raw material which does not require any inspection is allowed straight into the factory. Raw material which requires inspection follows on to the second area. In this second area, called *Inspection Selection,* one decides if the lot must be inspected, so that defective pieces are replaced by perfect ones (*rectifying inspection*), or if the lot analysis is to decide only whether the lot will be released for use or returned to its supplier (*inspection for acceptance*).

For the purpose of the application of the model we are studying here, quality inspection is regarded as the process aimed at determining whether a given piece, sample or lot complies with pre-established quality specifications, according to Aft [31]. Thus, inspection evaluates the quality level of a certain part or a set of pieces, comparing each piece or each piece with a pre-determined standard.

Some important information about inspection and raw material control is then given to the students, like the following.

The inspection aims essentially at providing a diagnosis of the product in terms of its quality level – see [32].

Such a diagnosis is always centered upon the quality characteristic, which consists of each and every elementary property that the product must possess in order allow it to work at full compliance with its project as well as with the function it was designed to perform.

It can be noticed that in both areas there are decisions related to raw materials flow. In the first case, such decisions have to do with sending the raw material straight to the assembly line or to an inspection process. In the second case, these decisions involve

1. allowing the lot in the assembly line, now as the result of an inspection process, or
2. returning it to the supplier.

For each case, we have developed and applied an Expert System to make the decision required.

A. Inspection Control Area

The basic decision in the first raw material reception area involves the establishment (or not) of the necessity of a given raw material that has just arrived to be inspected. In order to make decisions in this area; a Decision Support Expert System was developed which determines the most suitable choice as regards whether or not the development of inspection procedures for materials received is in fact necessary.

The Expert System in question makes use of a basic study previously developed to determine if inspection is really justifiable for some pieces or specific situations. This question stems, first and foremost, from what the inspection is intended to – fundamentally, it provides a diagnosis of the process, detecting defects, identifying situations of non-compliance, analyzing cases of non-fulfillment of basic functioning requisites and also carrying out particular evaluations of the product's quality characteristics along its different manufacturing stages.

The concept underlying the Expert System is simple. In general terms, inspection is deemed justifiable if fits within a broader process, being thus seen as a simple support activity. Rendering it adequate to control strategies or to the process evaluation methodologies will then be essential to determine whether it must be carried out or not.

Carrying out an inspection is justifiable only after the criterion exposed above has been attended to, e.g., that the inspection fits within a broad quality evaluation process, so that its results can be analyzed and taken into consideration when the general actions of the Quality System are defined.

The objectives of the inspection ought to be simultaneously considered with this general criterion. If what we seek is only suppliers' quality evaluation, inspection may not be the most appropriate means of obtaining such information, since it provides more specific considerations and emphasizes particular aspects of pieces. However, a whole group of inspections duly put together and analyzed could serve that purpose – which would not be true for individual inspections.

Together with these broad guidelines, sometimes rather generic, other more specific aspects could be taken into account. Such particular considerations, in complete consonance with the general criteria described, show well-characterized practical situations, although likely to be found in a large number of products and processes in which inspection is highly recommended and others where it simply does not seem reasonable to be carried out.

Inspection cost in view of the importance of a given piece is one of such aspects. If inspection cost is too high, inspection is not justifiable. In this case, control could be carried out by some activity subsequent in the productive process or by testing a given set including the piece in question. A combined analysis would thus compensate high inspection costs of individual items.

A related aspect has to do with the cost of the unsatisfactory product. If this cost is exaggerated, inspection should be carried out. Otherwise, it should probably not.

Whenever the raw material immediate use phases involve covering operations or alterations on face or external features of the piece, inspection is justified. In more general terms, if the following operation in the process is of extreme importance for the product, inspection is required.

There are cases where inspection is necessary as a means of performing essential tasks related to raw material analysis. Some examples, here are discussed with the students. This happens when inspection is used for classifying pieces, for instance. The same situation takes place if the product has many characteristics to be controlled. On the other hand, inspection ceases to be relevant if rejection of the product does not interfere with the disposition of using it. In this case, testing the product is not justifiable if such an evaluation results in no change on its effective utilization. It is practically the same as making no use of the inspection results. If such results are not taken into consideration, there is no reason for us to get them and, hence, no reason for us to carry out the inspection.

The inspection can still be considered within the context of the productive process as a whole. We may choose not to proceed with an inspection where the supplier's history shows a high performance or where techniques of Statistical Control of Processes determine that the productive process is under control, having full compliance with the specifications of the project [33].

In such cases, if the capability value of the process is reliable and meets the specifications of the piece, inspection may, at least, be mitigated. However, if the evaluation of a supplier's previous data reveals a proneness to produce defects that become more serious in the following phases or simply propagate along them, inspection is then recommended.

In view of the specificity observed, we have detected the need of designing a Decision Support Expert System which makes possible to determine the best option to be adopted in a given situation, where it becomes necessary to decide effectively whether or not an inspection should be carried out. This is the aim of the present system, which compares the benefits and restraints of carrying out an inspection at this point in the process and defines the posture to be adopted.

It is noteworthy the fact that in other areas of Quality Management, Expert Systems have been used successfully (see, for instance, [34], [35]).

B. Flow Control System 1

This is an Expert System based on rules, having 66 rules and 30 qualifiers. The system can list all the qualifiers as well as the rules in which the choices were used. In this case, the choices appear in all the rules used for the decision. The decision of the Expert System has to do with carrying out or not the inspection. The scale of values used by the system is made up of (integer) values ranging from 0 to 10.

The adequacy of the option chosen is made evident when values close to 10 are given to it; its inadequacy is characterized by values close to 0. All the rules possible are deployed in deriving data for the selection of the most suitable choice. The system does not show the rules while they are being used. Notwithstanding, the student may alter this option.

As an example of a rule we have:

IF Rejection of a product precludes its use,
THEN Inspection should be carried out – Probability: 9/10; Inspection should not be carried out – Probability: 1/10. (Rule 24).

As an example of a qualifier we have:

The immediate phase of use of raw material

1. is costly because it uses expensive materials;
2. is irreversible;
3. implies high execution costs;
4. does not have special characteristics. (Qualifier 21).

Most of the rules have bibliographical references, providing them with a conceptual background. Some rules also have explanatory notes as to their formulation or concepts therein included.

The system is made up of 5 basic areas involving analyses related to the nature of the inspection, of the product, of the process and of the lots, as well as a quality level analysis of the process.

In broad terms, these areas involve the following aspects, amongst others:

As to the nature of the inspection:

1. inspection cost levels in view of the importance of the piece;
2. inspection efficacy level;
3. general objectives of the inspection;
4. nature of the tests for carrying out the inspection;
5. effects of the inspection on specific phases of the process;
6. defect occurrence possibility;
7. necessity or convenience of classifying the pieces;

As to the nature of the product:

1. characteristics of the product to be controlled;
2. consequences of rejecting a defective product;
3. cost of products non-compliant with the project;
4. relation between defect occurrence and manufacturing phases of the product (e.g. probability).

C. Inspection Selection Area

The raw materials which Area 1 Expert System released will be forwarded straight to the assembly lines without inspection. The others will be submitted to a new Decision Support Expert System which determines the most suitable choice in the case of a decision between quality inspection only for acceptance (or rejection) of raw material lots, and quality inspection for lot rectification.

It is worth pointing out that the decision here involves the purpose of the inspection, i.e., it can be sorted out into two types: lot inspection exclusively for acceptance (or rejection) and inspection for correction for upgrading the quality level of a given lot, therefore altering its value.

Both types of inspections are discussed with the students.

The first case consists of inspection for acceptance – inspection is aimed only at detecting defective pieces in a lot to determine whether the lot should be accepted in its completeness or rejected, considering thereto maximum values of those defective pieces. Thus, this type of inspection is limited to accepting or rejecting the lot based on the analysis of a sample taken from it.

Acceptance implies releasing the lot for use; rejection means that it should be returned to the supplier. This type of inspection is called ‘inspection for acceptance’, since it consists only of an evaluation in order to determine what to do with the lot – accept it (which means its habilitation for effective use in the factory) or reject it (which means sending it back to its origin, i.e., returning the lot to the supplier).

The second type involves rectifying inspection. If we do not want to return the whole lot, we may carry out an inspection aiming at replacing defective pieces by perfect ones. In this case, we work on a sample of the lot initially. Each defective piece found in the sample is replaced by a perfect piece. If the number of defective pieces is lower than a given limit, the lot is then accepted and released for use. Here, only those defective pieces from the sample were replaced. If, however, the number of defective pieces should exceed of a pre-established limit, then the whole lot will be inspected with replacement of all the defective pieces by perfect ones. This is what we call *rectifying inspection.*

There is a fundamental difference between these two types of inspection. Inspection for acceptance determines the quality level of the lot, but it does not go any further than that, whereas rectifying inspection, in addition to determining the quality level, makes it better by means of replacement of defective pieces by perfect pieces. Of course rectifying inspection shows the same problems as a complete inspection, i.e., there is no guarantee that all the defective pieces, whether from the sample or, in case of rejection of this sample, from the whole lot, will be effectively detected and replaced.

Therefore, it is said that rectifying inspection tends to improve lot quality, although it is not guaranteed that at the end of the rectifying process the lot will have a 0% rate of defective pieces. This happens because of both considering the situation in which the samples were accepted (in this case the rest of the lot has not been analyzed), and observing the natural practical difficulty to detect all of the defective pieces of the lot (in those cases of rejection of the original sample).

D. Flow Control System 2

It consists of an Expert System based on rules, having 47 rules and 22 qualifiers. The characteristics of the system are the same as those of system 1. Thus, for instance, the system can list all the qualifiers as well as the rules where they are being used. It can also show all the rules in which the choices were used. In this case, the choices appear in all the rules used for making the decision.

There are two options for decisions here: Inspection for Acceptance or Rectifying Inspection. Here too the adequacy of the option chosen is made evident when values close to 10 are given to it; its inadequacy is characterized by values close to 0.

As an example of a rule we have:

IF there are perfect pieces in stock and at low cost,
THEN Inspection for acceptance – Probability: 2/10; Rectifying Inspection – Probability: 7/10. (Rule 25).

As an example of a qualifier we have:

The inspection is carried out in terms of

1. raw material from various suppliers and easily available;
2. raw material from various suppliers and of difficult availability;
3. raw material from exclusive suppliers.(Qualifier 28).

Like the previous system, most of the rules have bibliographical references, providing them with a conceptual background. Some rules also have explanatory notes as to their formulation or concepts therein included.

The system is made up of 4 basic areas involving analyses related to the nature of the inspection, of the process and of the lots, and it also takes into account the suppliers and raw materials. In broad terms, each area involves the following aspects, amongst others:

As to the nature of the inspection:

1. role played by the inspection in the quality of the process;
2. actions resulting from the inspection;
3. general objectives and emphasis given by the inspection;
4. scope of the inspection in relation the productive process;
5. areas of action of the inspection;

As to the nature of the process:

1. evaluation of the supplier’s average quality level;
2. general characteristics of production planning and control;
3. stocking structure;

As to the nature of the lots:

1. relation between lots and samples;
2. use of lots of pieces after the quality evaluation decision;

As to suppliers and raw materials:

1. relationship with suppliers in terms of quality control of the lots purchased;
2. raw material reposition levels.

Since we have finished the application of the set of expert systems, we began to evaluate its impacts to the students.

VIII. Evaluating the experiment

The present study shows the basic aspects of an active and interactive learning method. We try to highlight their advantages. As we can see, some studied models of the interactive teaching have been applied with technological support to the hardware and software areas and adapted to Engineering courses.

In a general analysis, the use of Expert Systems has an objective (the same objective of the proposed model): to adopt an active and collaborative learning process. Active in the sense that effective student participation is required in the situations which simulate the application of motivation strategies. And collaborative in the sense that the situations will only be clearly understood if students respond to the stimuli provided.

The active and interactive learning process has been used in Brazil for a long time. In fact, there is a common sense in Brazil that this is a highly useful and effective way towards learning. Nonetheless, despite the consensus that the process is relevant, it is, in general, hardly seen in practice. And three common postures can be said to exist, as follows:

(1) Students are led to participate through a question-response model. They participate actively through their responses. New questions are asked based on their previous responses.

(2) Students conduct practical experiments under the teacher's supervision. Discussion of such experiments is the most important element in the process.

(3) Students seek practical situations outside the classroom environment and discuss them in class. Again, this is when the process reaches a peak.

Hence, two characteristics make the present model stand out from other similar experiences:

(1) The strategy to be taught is learned through simulation of the strategy itself in classroom;

(2) Students are the target of the strategy. They learn because they are part of the process.

In Brazil, this process does not require written rules or norms. Rather, it reflects, to a large extent, common classroom practices shared in congresses, seminars and meetings. The present model went through this process: it was discussed in five regional congresses and gained widespread acceptance. It is clear, however, that the best evaluation came from students.

At this point, Table 1 can be presented, where the results of the application of the model to twelve groups of students (different Engineering classes of the first and the second semester of 2007) are displayed. The data show that the model has both widespread acceptance and good development potential. Table 2 shows how the students evaluate the use of Expert Systems in learning process. And Table 3 shows the evaluation of the topics used in the experiment.

Question: ***Simulating the strategy in the classroom ...***	**Certainly**	**Yes**	**Not always**
1. *... improves learning?*	89 %	4%	4%
2. *... is better that the usual process?*	86 %	6%	4%
3. *... gets students effectively involved?*	84 %	10%	3%
4. *... should become more widespread?*	89 %	5%	3%

Question: *Simulating the strategy in the classroom ...*	**Certainly not**	**Students involved**
1. *... improves learning?*	3%	1,045
2. *... is better that the usual process?*	4%	1,054
3. *... gets students effectively involved?*	3%	1,061
4. *... should become more widespread?*	3%	1,049

Table 1: Evaluation of the model by the students (notice: only valid responses were computed.)

Question: ***The use of Expert Systems ...***	**Certainly**	**Yes**	**Not always**
1. *... improves learning?*	79 %	11%	4%
2. *... is an attractive strategy?*	81 %	10%	5%
3. *... gets students effectively involved?*	80 %	14%	4%
4. *... should become more widespread?*	85 %	10%	3%

Question: ***The use of Expert Systems ...***	**Certainly not**	**Students involved**
1. *... improves learning?*	6%	1,042
2. *... is an attractive strategy?*	4%	1,053
3. *... gets students effectively involved?*	2%	1,055
4. *... should become more widespread?*	2%	1,044

Table 2: Evaluation of the use of Expert Systems as a learning strategy (notice: only valid responses were computed.)

Question: ***The topics used in the experiment ...***	**Certainly**	**Yes**	**Not always**
1. ... *improve learning?*	81 %	8%	5%
2. ... are *attractive?*	85 %	5%	6%
3. ... *get students effectively involved?*	86 %	4%	6%
4. ... *should be replaced by other ones?*	5 %	5%	4%

Question: ***The topics used in the experiment ...***	**Certainly not**	**Students involved**
1. ... *improve learning?*	6%	1,039
2. ... are *attractive?*	4%	1,049
3. ... *get students effectively involved?*	4%	1,045
4. ... *should be replaced by other ones?*	86%	1,054

Table 3: Evaluation of the topics used in the experiment (notice: only valid responses were computed.)

IX. Conclusions

The first tests developed with distance education process showed that the equipment adapts to the interactive process, which is normally absent in these situations. They have so far revealed a perfect adaptation to a teaching/learning model, which requires the students' effective participation. Remote classrooms located in ten different cities, where are the students who interact with teachers from Florianópolis (where they live) show that the hardware selected for the process is adapted to the context desired for an interactive teaching.

It is interesting to note that the same conclusions have been arisen from e-learning experiences [36]. Shimomura et al [37] stand that it must be considered that "E-Learning is not almighty, nor can it teach everything". But, the same authors stand, "On the other hand, e-Learning is very suitable for playing such auxiliary roles as help teachers estimate the effectiveness of their lessons or help students know the current status of their abilities". That is the situations we are studying here.

Artificial Intelligence, in turn, has proved to be adequate to interactive teaching. In fact, this area provides computer techniques whose characteristics are not found in common programs. Indeed, we wish to make use of a methodology that introduces new knowledge to the problem wherever convenient, due to the process development itself. We aim at separating knowledge itself from evaluation process of the control structure of the ES, which manages its whole development. We thus seek to give as much flexibility as possible to the computer program in use in the System. We also expect some results in terms of solutions proposed to the problem in certain cases to be satisfactory – but not necessarily optimum, in view of the evolutionary characteristics typical of a learning process. Such aspects, all usually addressed to AI approach, show that this technique is more adequate to this problem than the traditional approaches.

A relevant point to be considered here is the fact that we are not proposing a solution that requires broad common-sense but, rather, we intend to determine practices that seek to make more objective and practical those procedures, traditionally developed in a subjective way.

Once the adequacy of the basic methodology (AI) has been checked, it becomes clear that the tools deriving thereof are also applicable to the case being studied. This can be noticed, for example, in relation to ES – an aspect of fundamental importance to the whole project. It is worth to point out that solving the problem involves situations with basic characteristics that meet the requirements of the solution methods based on knowledge. Some of such characteristics are: (a) the use of rules (or other structures) comprising knowledge and experience of experts in the subject; (b) the employment of logical inference; (c) the interpretation of ambiguous facts; (d) the handling of imprecise knowledge, i.e., knowledge affected by certain factors. In fact, AI techniques are fully used in the ES. A computer program with this approach should be able to report information in an intelligent way, produce inferences, as well as justify them (the same should be true to the final results to the problem).

Finally, it is necessary to call attention to the fact that, with the use of technological support at both hardware and software levels, it is possible to determine the feasibility of interactive teaching processes, fully adapted to several situations. It is only a matter of dedication and willingness to create more adequate ways of preparing the engineers whom our country needs.

Maybe the most relevant conclusion of this experiment is related to two basic aspects. Firstly, there are many ways of getting students involved in the teaching–learning process. For any of these, however, considering students' human aspects from the perspective of their involvement in the process seems to be fundamental if one expects an effective response from them to the stimuli each course intends to offer.

The used Expert System gives an effective answer in this direction.

Secondly, it is necessary to bear in mind that the best involvement model is not that which the teacher deems easier to implement or the most suitable in terms of his/her own profile as an educator. Rather, the best model is that which can be adjusted to his/her students' reality. Thus, for example, in many cases the classic approach will substitute for the participatory model (for instance – answering Expert Systems questions) if the purpose is to adopt discipline; in others, students may be considered to be sufficiently aware and mature to face participatory strategies or, still, the teacher may realize that only by having their attention drawn can he/she obtain responses to stimuli.

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