Description, analysis and test of an autonomous computer aided learning module for digital control

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Abstact : This paper presents a set of pedagogical solutions and their analysis for an autonomous computer aided learning module. The content of the module is "An introduction to digital control", based on a real (but simulated) system : the automatic air conditioning system inside a modern car. These rather theoretical contents are presented without any mathematics to our non specialist students, according to a pedagogy of the inductive type. Our added value lies in the module structure and in its evaluation. The student opinion is tested about utility and easiness of the contents, utility of the computer for training, usability of the computer in an autonomous way and motivation. The analysis put in evidence a less large positive opinion after the training course than before.

The module (in french) could be seen on : http://www2.toulouse.iufm.fr/ganesha with "demo" and "demo"

I. INTRODUCTION

This project started in 2001 in our "Institut de Formation des Maîtres de Midi Pyrénées" which is a Teachers Traning Public University [1]. It was a proposal for the call for « digital campus » launched by the « Direction de la Technologie » in the french Ministry of national education and research.

II. THE PROJECT ARCHITECTURE

A. The project initial objectives for our institution

The project initial objectives were :

- to offer training possibilities adapted to the public (distance, occupation, time...), a way to learn "when and where I want",
- to make the students acquire in autonomy, scientific, technical, technological, methodological and didactic skills. These skills are necessary to teach automobile maintenance in adequacy with the permanent evolution of the market,
- to get experience in the field of distance and computer aided autonomous learning.

B. Specific competences of the secondary electromechanical teacher

The future teacher must be able:

- to organize a lesson according to official and institutional requirements and taking the local constraints into account,
- to prepare, implement, control and evaluate different training courses according to several methods,
- to conceive, implement and to analyze a lesson, including a significant part of computer aided training in order to guide the pupil towards a more autonomous training.

B. Public definition

This module was built for a particularly type of students : pre service training of students, holders of graduate at the L (Licence) level in order to prepare the competitive examination recruitment as to become a government official secondary teacher in France. They were all "young", between 24 an 32 years old. Their background generally includes electromechanical knowledge and skills, but without any initial knowledge on digital control, either on Laplace transform or on Z transform. These contents which are frequent in the M level, are not part of the program of the competitive examination they have to pass. Then, the students may consider it as un-useful and we will have to check their motivation. Moreover, these teachers will only have to help their pupils to get a global vision of a digital control, to make them understand how it behaves and what are the tuning factors. Then, only a pedagogy of the inductive type was suitable in this case.

III. SOME EGONOMIC ELEMENTS

The hyper media resource could be studied according to 4 axes :

- utility,
- usability,
- acceptance,
- motivation.

Utility deals with the pedagogical scenario, usability focuses on the navigation scenario while the acceptance criterion gives information on the module compatibility with the student constraints, personal objectives, resources, and the institution requirements. At last, motivation could influence all the previous aspects and have to be checked.

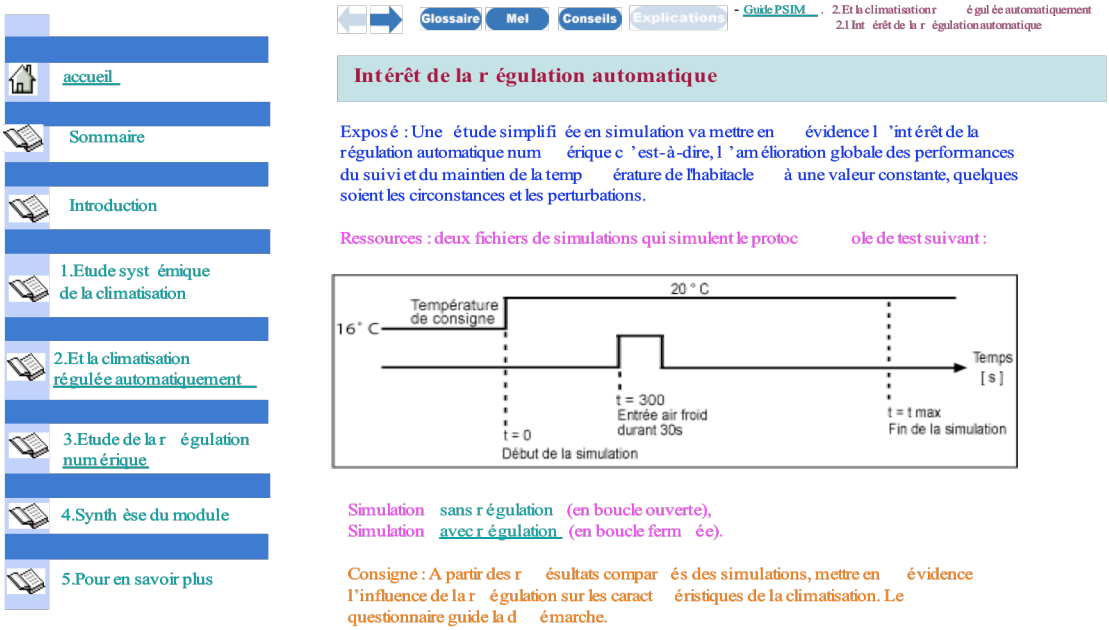

Fig 1 : Example of a web page with the navigation items, colours and icons

This way, we made very basic choices in order to remain simple and to privilege usability and acceptance, as depicted on figure 1 :

- 5 colours for the different kinds of text, each one devoted to a specific kind of text : a colour for the context, a colour for the task, a colour for the advices and a colour for the resources.
- These colours are stables, the relationship between a colour and its signification remains constant all along the module and on the different web pages,
- A specific attention is paid to affordance of the icons, which are in a limited number, always at the same place on the different screens,
- Flash animations are used only when necessary, for example on figure 2 to help to understand what occurs in the closed loop, among the different kinds of information : the computer output, temperature sensor output and pulses for the stepper motor…

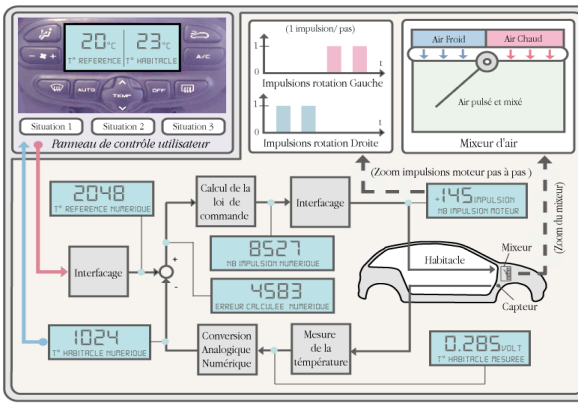

Fig 2 : Example of a flash animation

- A balance between depth and width is respected: the module includes 5 chapters (width) with a maximum of 4 points each (depth).

IV. ELEMENTS FOR A PEDAGOGICAL SCENARIO

A. A module inside a complete sequence

The module entitled « Introduction to digital control » is a part of a whole sequence dedicated to feedback and control. Table I presents its global organisation and the place of this module among the others. We assume it is not self sufficient to reach all the objectives. Then, the whole sequence mixes :

- different methods : lectures and measurements,
- different and successive teachers, A and B,
- different resources : web pages, paper documents that the students have to fulfil,
- different and successive but personal students activities : read, measure or simulate, compare and analyse the results in different cases, criticize them and test their validity, write a personal synthesis, compare with the positions of the other students, try together to get a consensus, debate and argue and at the end, built a solution with the teacher as a supervisor.

B. The choice of the inductive method.

The inductive method is used because it is efficient and useful for autonomous learning of the students themselves. Moreover, as they will have to practice it with their own pupils when they will be on service teachers, we think that the sooner they practice for their own learning, the better.

Table I : Screenplay of the pedagogical sequence

Module n°	Title	How	Teacher n°	Taxonomic levels	Time
0	Sequence presentation	presential	A et B	○ **Knowledge** : sequence and module, learning course planing, objectives and prerequired knowledge	15 mn
1	Lecture « introduction to continuous control »	distance learning + mail	A	○ **Knowledge :** open or closed loop, 1° or 2° order time response, ○ **Comprehension** : describe different types of time response, ○ **Analysis** : effects of the closed loop,	4H
	Mesurements on systems with linear continuous feedback	presential	A	○ **Knowledge :** open loop, closed loop, 1° order type or 2° order type time response, ○ **Comprehension** : describe different types of time response, ○ **Analysis** : effects of the closed loop,	6H
2	Mesurements for the tuning of P, PI continuous controllers	presential	B	○ **Knowledge :** experimental tunings of PI and PID controllers, ○ **Comprehension** : PI, PID controllers effects, ○ **Application :** experimental tuning of continuous controllers, ○ **Analysis :** comparaison of the tuning methods and interactions between the P, I and D actions,	6H
3	Lecture and mesurements on « introduction to digital control »	distance learning + mail	B	○ **Knowledge :** functional architecture of the automatic air conditioning system, ○ **Comprehension** : controller effects, ○ **Application :** recognize open and closed loop, ○ **Analysis :** compare and explain the different results for different parameter levels, ○ **Synthesis** : influence of the parameter levels,	4 H
	Collective synthesis of the module	presential	B	○ **Analysis :** compare and synthesis of the individual ○ **Synthesis** : parameter influence, ○ **Knowledge** : PI controller discretization	2H

C. Autonomous learning versus learning with a teacher

Our module is based on a real system. The concrete plant is first presented, with all its characteristics and then placed in specific and simplified conditions. For this module, the support device is the automatic air conditioning system of the Peugeot 206 CC. This module application centered and is able to a give learning sense, to answer questions such as "when and where will I find this case ?", "how is it in a real system", « is it really useful ? ». Application first !

D. Students' activities

Because learning is an active and personal process, **« on apprend que si l'on fait »**, each knowledge, everything to learn is linked to something to do. On each web page (introduction expected), a task is prescribed to the students. Some complex tasks are sometimes divided in more elementary tasks. We supposed that the simple principle « one web page = one question » could allow a rapid and clear identification of the problem that they have to solve.

In order to improve the student motivation to learn, on one the hand and to face the job diversity of a teacher, the prescribed tasks are of different kinds. They need different activities with different resources. For example, each student has to :

- first add some words in an existing bloc-diagram of the manual air conditioning system,
- later draw their own functional analysis of the automatic air conditioning system, share it and compare it with his colleagues,
- find the connection between the functional blocs and the real elements of the system (compressor, computer, sensor…),
- get the right parameters for a digital controller in a simulation, drag and drop the results in a text document, print it and analyse the results,
- read documents, answer questions and compare with solutions, write analysis that will be shared with other students during the last phase in presence of the teacher.

The professional world stresses the concepts of transferability, of training throughout the life with computers. The transferability purpose is re-using in other contexts, a knowledge acquired in a particular context. In this article, students work on transferability when they use a knowledge from previous modules (effect of the proportional gain in continuous control for example), in order to acquire a new knowledge (effect of the proportional gain in digital control).

Because it is useful and because the students do not often see the relationship between the contents they are taught, especially when different teachers are involved , an explicit and accurate reference is made to previous contents. We do not only mention the pre required knowledge or skills, but also recall when, in which part of a previous lecture or practical activity and with who this content was previously seen.

The acquisition of competences, must be possible all year long, mainly by problems case learning, from the professional field of maintenance of the vehicles. We propose to classify the students' activities according to three axes of training, as drawn on figure 3:

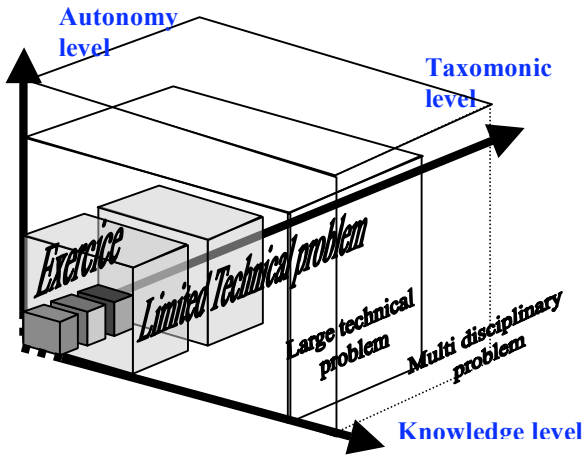

Fig. 3 : three axis to classify a student activity

- **Knowledge level:** this axis defines a hierarchical knowledge division from the smallest element to the environment of the whole system : matter, component, structure, function, object, man, systems, environment,
- **Autonomy level:** this axis characterizes the level of integration of knowledge in terms of assimilation and appropriation. It contributes to develop capacity to face new problems,
- **Taxonomic level:** this axis based on the Bloom taxonomy [2], from simple knowledge up to synthesis and expertise, precisely defines the behaviour of the students in relationship with their intellectual activity.

In this autonomous computer aided learning module devoted to an introduction to digital control, the level for autonomy is rather low, not to disturb the learning process with cognitive overload. Autonomy inside the learning course could be guided by the teacher by e-mail, who could either give the answer, the way to find it (method), or only the place to find the method. The different corresponding taxonomic levels for each module are listed in table I.

E. Autonomous learning versus learning with a teacher

We think that the presence of the teacher remains unquestionable, but it has to be checked. This training action consist in successive phases of classical and autonomous learning, as depicted in table I. The autonomous learning is always included between two sequences of classical course, one at the beginning for objectives, tasks, rules… presentations and one at the end for collective synthesis.

F. About the interactions between the students

The need for the communication (between students, with the teacher) is highlighted in many references. It seems that communication is able to compensate the relative isolated position induced by the solitary use of a computer. Moreover, communication makes possible to set up a formative evaluation and carries out the essential feedback which is necessary for the teacher to guide the trainings. This aspect was not studied in this paper.

V. THE SOFWARES

Our system is supported by the Ganesha platform, [3], which was in 2001 when this project began, the only free, open source (and in French) platform.

The automatic air conditioning system is simulated by functional blocs. The students only have to plot the time response during a specific test benchmark : step input from 16°C as an initial temperature inside the car to 20°C reference temperature, disturbance rejection as a cold air input in the vehicle when the driver's window is opened at a toll stop on a motorway for example. The simulation software is Psim [4], the free demo version is sufficient for the simulations included in the module. These students only use this software as a simple simulation tool, they do not need to be qualified on this type of software. Moreover, an online help gives them the main information "how to simulate", "how to plot", "how to drag and drop"…

VI. EVALUATION OF THE LEARNING MODULE

A. Evaluation procedure

Our added value lies in the particular module structure but mainly in the evaluation of this distance learning module. It focussed on utility of contents, usability of computers, acceptance and motivation. Two groups of students (8+6) from different curricula (8 students with mechanical profile and 6 students with electrical engineering profile) where tested according to the same procedure : a first paper test before any login at the beginning of the autonomous computer aided learning module and the same final paper test at the end of the afternoon. The results are almost the same for the two groups and theirs answers have been analysed together. Both questionnaires include the same questions:

- The first part of the paper test for their performance on the contents through 5 open-ended technical questions, on the effects of the proportional gain, of the sampling period or of quantization… on the performance (stability, precision…) of the closed loop system,
- The second part of the paper for utility, usability, acceptance and motivation where the answers, noted on a 4 levels Lickert scale, could be very negative (=1), negative (=2), positive (=3) or very positive (=4). Theses items are mainly the object of the following analysis, but the students' results on the first

part of the test, will be also studied.

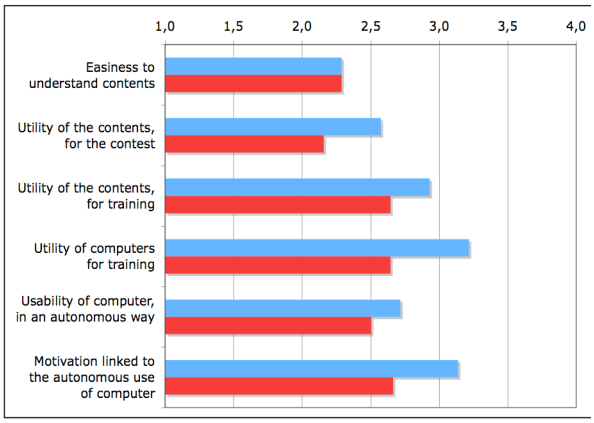

Fig. 4. Means scores on six questions about students' opinions before and after the training course

Figure 4 draws the results on bar-graphs. The students' average opinion is a little higher (M=2,67) than the median. It is better before (M=2,81) than after the training course (M=2,48).

As only two students out of 14 have had previous experiments in using computers in self-training, 12 students did not have any previous experiment in the field. Anyway, none of them was a complete beginner with computers as they all daily practice mail, Internet and computers for text, computer-aided-design…

B. Utility results

Our module was rated by all the students of the 2 types, as not very useful for the selection they have to pass (score = 2). This is mainly due to the fact that the topics "system control" or "feedback tuning" are very rarely tested in that type of selection each year. Students focus on the most frequent topics and disregards others, particularly if they seem too theoretical. Therefore, the students consider this content as of little importance for their future work because the score is 2.5 (mean level) and it is rather the same before the learning session and after the learning session. On the three required judgments of utility (contents for the contest, contents for training, autonomous use of the computer), the judgment is less favorable after the training course than before. The two feelings of easiness are also less favorable after (autonomous use of the computer) or do not move (understanding contents).

C. Motivation results

It seems to be well known that the use of a computer is a motivating tool for self learning, especially in domains like electrical engineering. We tried to question this point and the results are not so good. The motivation is less large after than before, which is generally the case observed in the evaluation of the devices of teaching and training [5], [6]. Then scientific or technological curricula, such as in [7] must take into account this widely spread opinion among the students. The assumption that a larger use of computers first and the possibility to study in an autonomous way do not seems to be certain and indisputable. All differences are not significant (probably because of the small size of our population). Nevertheless, the hazard probability is less than 12 %.

The students experienced in using computers in self-training seem to be more motivated than others, especially after the training course ($F = 7{,}636$; $p < {,}05$) and their motivation does not decrease.

D. Usability results

The opinion about the usability of the computer does not seem influenced by the judgment of the utility of the contents for the contest. It is the same for the motivation to use the computer: it does not seem influenced by the perceived utility of the contents for the contest (nor for training). Anyway, the students opinion about usability is less large after than before the module.

E. Opinion on the teaching method

The student opinion about the teaching method, (if they prefer autonomous computer aided learning only or a mixed method with computer and in presence of the teacher) as also been checked. It is summarized on figure 5 and they are dramatically the same before and after the training module. The underlined numbers correspond to the students already experimented in computer aided learning.

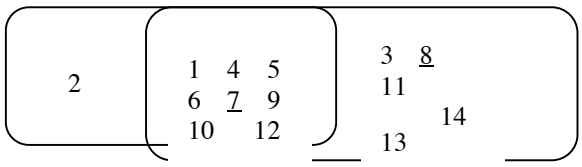

Fig. 5 : distribution of the students opinion versus the teaching method

It is obvious that most of the students prefer a composite method with a computer and with a teacher. Only one out of 14, prefers an autonomous computer aided module. They prefer to study with their teacher and not only with a computer !

F. Performance of the students on the topic

All students where not experimented at all in digital control before this module. With a little emphasis, it could be said that the only thing they know, is that there is a computer inside and that topic is very

complex !

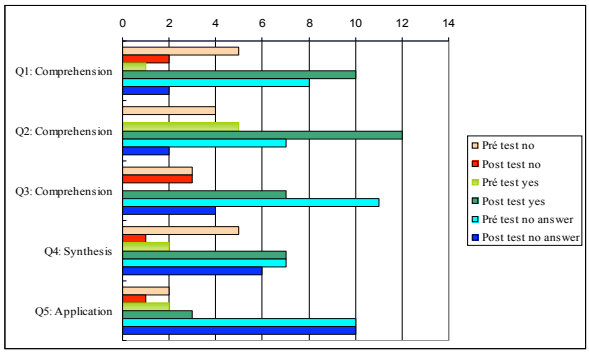

Fig 6 : Performance of the students
before and after the training course

Table II : test questions with the associated taxonomic levels

Q1: Comprehension	Influence of the sampling period on the performance
Q2:Comprehension	Influence of the gain on the performance
Q3: Comprehension	Influence of the discretization on the performance
Q4: Synthesis	Comparison between continuous and digital control
Q5: Application	Tuning method of a digital controller

The performance of students versus the technical contents are depicted on figure 6. According to this figure and for this item, the effect of the computer aided autonomous module is rather good. It can be seen that the non satisfying answers are fewer after the test than before the test, and that on the contrary, the number of satisfying answers increases

VII. DISCUSSION

According to [8], a user's acceptance of technology is affected by different factors such as: the extent to which the features of the technology are consistent with the user's needs, the user's experience with the technology, the user's awareness of technology and of purpose. In our study, the decrease of the acceptance follows the fall usability of computers.

Computer competence affects individual satisfaction with computer use in training courses. [9] compared the effects of four types of computer experience on 30 graduate students' learning of a statistical program over one semester. Among the four types of computer experience, students' earlier experience of using computer network systems was found to affect their initial performance of learning the statistics program, but the experience of using statistical programs, the experience of email programs, and the length of using computers did not. All students where almost all equally experimented, nothing could be tested on that subject.

These contents are rather theoretical and conceptual, and there is a real to difficulty for the public. In addition, the navigation questions "where am I", "what remains to be made", "when it is finished" increases the stress for the students. It seems more relevant in the future, to cut out this difficult and long module in small pieces, which the teacher could put in access to such or such moment. Then, the teacher's job will increase but something is probably more important. Is there any risk to move away from the application and thus, loose the global vision of the system, loose a part of the motivation and even the sense of their learning actions ? This assumption will be tested in future works.

VII. CONCLUSION

This paper has presented an autonomous computer aided learning module for digital control. The main ideas that structured the module have been presented. The training course have been tested and the results can globally be classified in two sets. As a first part, the module is rather efficient for the contents, the objectives are reached by most of the students. On the other hand, the use of a computer for autonomous learning leads to some conclusion : motivation, utility and usability of computers for autonomous training decreases. They prefer to study with their teacher and not only with a computer !

VIII. REFERENCES

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