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Refining Statistical Problems: A Hybrid Problem-Based Learning Methodology to Improve Students' Motivation*

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Statistics is fundamental to many disciplines and plays a central role in Engineering and Sciences. To understand and apply statistics requires students to be highly motivated. Therefore, fostering students' learning and reducing dropout rates implies increasing students' motivation. We present a guided problem-based learning approach to teaching statistics in hybrid learning environments and we analyse its impact on students' motivation. We pay special attention at subdividing problems into small sections to obtain detailed sets of questions associated with specific concepts or procedures. This degree of detail guarantees that students can easily tackle these problems in virtual learning environments. In addition, thanks to the use of automatically generated log files, our proposal allows teachers to finely analyse the steps in which students have difficulties. We assess our proposal in terms of student satisfaction and motivation. The results show that although success rates are not improved, students' motivation for the subject increases. Consequently, our approach is a good choice to improve motivation and reduce the dropout rate in difficult subjects such as Statistics.

Keywords: PBL; statistics; virtual learning environments; motivation

1. INTRODUCTION

> It is, in fact, little short of a miracle that the modern methods of education have not yet entirely strangled the holy curiosity of inquiry; for this delicate little plant, aside from stimulation, stands mainly in need of freedom; without this it goes to wrack and ruin without fail.
>
> Albert Einstein (*Autobiographical Notes*, 1949)

WHEN ALBERT EINSTEIN WROTE the above sentence, understanding of the learning process was radically different from current understanding. Now students are placed in the centre of the learning process and teachers are no longer oracles but guides. There is a clear view of the social function of Higher Education that is essentially guided by: (i) the pursuit of excellence in teaching, training, research and institutional performance; (ii) the relevance of services offered by higher education institutions to the perceived priority needs of their respective societies; and (iii) the quest for balance between short-term pertinence and long-range quality, between basic and applied research, and between professional training and general education.

Having this social function of Higher Education in mind, UNESCO proposed several recommendations affecting national and institutional policy-making, the content of Higher Education (i.e. training, teaching and research), and the contribution of the actors involved [1]. Amongst these recommendations, the following specially motivates the research presented in this paper.

> . . . promote innovation in content and methods which can assure enhanced access to higher education while still preserving the quality of education and its relevance to social requirements. (This strategy should take into account the potential of distance education and information and communication technologies, the globalisation of the curriculum and the contribution of pedagogical networks for staff development to improve teaching and learning at the higher education level). . . .

Indeed, the use of information and communication technologies (ICT) is essential in order to innovate in teaching methods. ICT are present in all sectors of our information society. Education is no exception and ICT are used more intensively with each passing day. Moreover, the existence and use of open-source software (e.g. [2] and [3] are recent examples of open-source software utilisation for teaching), and the widespread access to the Inter-

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net paves the way for the use of computer-aided teaching techniques.

Considering the degree of proximity between teachers and students, teaching methods can be classified between two extremes. On the one side, classical methods rely on face-to-face teaching; on the other, students and teachers are only connected virtually through computer-aided techniques. Between these extremes hybrid approaches that combine the traditional face-to-face teaching methods with innovative on-line techniques can be found. Hybrid courses offer students the advantages of ICT (e.g. on-line courses are asynchronous, easily accessible and learner-centric) without loosing personal contact with teachers and other students. Hybrid approaches are also known as blended instruction or b-learning tools. A detailed analysis of blended learning tools can be found in [4, 5]. In this paper we focus on this kind of courses.

Many papers that study the use of ICT to improve the traditional lecture format have been published. Alldredge and Som [6] studied the impact of incorporating multimedia presentations into the traditional lecture format. In [7], the author compares the performance and attitudes of students in a hybrid Statistics course and in a traditional face-to-face model. The results indicate that there are no significant differences in terms of grades, so this paper joins the group of papers reporting the No Significant Difference (NSD) phenomenon (cf. [8] for a detailed explanation of this phenomenon). However, students' attitudes seem to be more positive in the hybrid course than in the face-to-face one. In [9], the authors compare the students' perception of traditional versus blended learning methods. They conclude that despite the fact that no significant differences in terms of student satisfaction were found, the dropout rates were lower in the blended course. These results contradict those in [10], which pointed out that students' attitudes were more positive in face-to-face courses. Many other comparisons between hybrid and traditional teaching approaches can be found in the literature [11–13]. Although most of the comparisons conclude that there is no significant difference between online and traditional courses, hybrid courses seem to increase the satisfaction and motivation of students and, thus, the dropout rate decreases.

If we focus on Statistics, we can observe that it is a very broad subject with many branches that range from statistical theory to its application in biology, medicine, social sciences, engineering, physics and economics. In fact, there are few disciplines that do not use Statistics. In the US, the curriculum objectives described by the Accreditation Board for Engineering and Technology (ABET) are the basis of most of the recommended Statistics courses. In the EU, the new European Space for Higher Education (ESHE) has also impelled the standardisation of higher education courses. However the challenge is to design Statistics courses that not only cope with the curriculum objectives but also promote positive student attitudes towards the topic. Although the methodology described in this paper has been applied to teach Statistics, it can be easily adapted to any discipline whose knowledge is related to the ability to solve problems.

Since comparing two different course formats is often impossible in educational research (cf. [14]), this paper can be considered to be an observational study centred on the analysis of student attitudes towards the new methodology used in the course. Specifically, the current study aims to assess whether the use of the new methodology has a positive effect on the students' overall satisfaction and motivation.

1.1 Our Motivation

Traditional teaching of Statistics, as well as other mathematical topics, has been related to problem solving. Therefore, a considerable number of books with detailed solved problems can be found. These books usually contain summaries of key theoretical points along with fully-solved problems. Although these books are very useful for consolidating the knowledge that students already have, they cannot show students the mathematical tools needed to overcome a step of the problem without revealing the complete solution. Thus, when a problem statement is provided without any additional guidance, students that have not developed the skills needed to tackle the problem may feel lost and, as a result, they remain stuck.

Traditional courses suffer from two important shortcomings that can affect students' performances: (i) they do not pay special attention to the growing diversity of students and, (ii) they cannot provide students with immediate and personalised feedback about their learning process.

Notwithstanding, the development of the Internet has facilitated the incorporation of b-learning techniques to teach Statistics in universities [15]. With the proper selection of those techniques, it would be possible to overcome some of the limitations described above. However, learning meaningful concepts, especially those implying a high degree of abstraction, requires students to practise several times before the concepts become solid and applicable to a variety of practical situations. Even when a concept is understood, the underlying procedure should be internalised in order to be successfully applied in practice. Thus, the regular use of concepts in appropriate practical assignments can positively affect long-term learning. Nevertheless, students usually find difficulties when they try to solve problems in cognitive domains that are new to them. Some of these difficulties are related to: (i) deficiencies in the conceptual understanding of the required topics and, (ii) lack of knowledge of proper procedures that should be followed to reach the right solution.

1.2 Contributions and Plan of the Paper

We propose a hybrid problem-based method to teach Statistics. Our method is based on the subdivision of complex problems into simpler shorter questions that can be easily answered online.

Our method combines face-to-face theoretical classes and on-line computer-aided practical classes. Instead of simply moving problems from face-to-face classes to on-line ones, we have redefined the problems themselves in order to simplify, clarify and improve the way in which students tackle them. Problems are divided into multiple questions that students may solve progressively. Thus, it is very easy to determine the point at which a student is stuck, and what the cause of their inability to continue is.

The rest of the paper is organised as follows. Our method is described in Section 2. Section 3 reports some data on students' performance and satisfaction along with a discussion of the results obtained. Finally, Section 4 concludes and points out some future lines of research.

2. DESCRIPTION OF THE METHOD

In this section we describe the proposed method, which is founded on two main points:

- to subdivide problems into sets of smaller questions;
- to use an on-line platform to access these problems.

In the next section (2.1) we explain the rationale behind the subdivision of problems. Next, in Section 2.2 we summarise the software tools that we have used to implement our proposal.

2.1 Refining Statistical Problems

We propose a methodology based on a collection of finely subdivided problems that are designed to be progressively solved by students on-line and to allow us easily to detect steps where students need teachers' assistance. In addition, by using an on-line problem-based method, we promote a learning-by-doing approach to the subject. Instead of displaying the complete statement of problems on the computer screen, each problem is split into several short questions, each focusing on one step of the problem, to guide students to the solution progressively. Consequently, students not only think about concepts but also learn how to cope with statistical problems, which are the most common steps, and which tools are needed.

In order to facilitate the gathering of feedback information we have defined three types of short questions/answers, namely multiple choice questions, questions that require a short answer and questions with numeric answers that require a small number of calculations and reasoning. These questions are presented to students gradually. Once they have answered a question correctly the next one is displayed in their browser. Additionally, after a fixed number of wrong answers to the same question the on-line platform provides students with the correct solution to prevent them from remaining stuck. This immediate feedback allows students to focus their attention on the points where they really need more help.

The design of the short questions is based on the principles of learning and logical thinking. The most common errors are identified and questions are formulated so that each wrong answer corresponds to a common misconception or misunderstanding of a specific concept. The contents of the course, and by extension of the designed questions, can be grouped into four main chapters, namely data management, random variables, mathematical estimation and, hypothesis tests. Some of the main topics covered in these chapters are: descriptive statistics, random variables and sampling, univariate analysis, least squares and regression, discrete and continuous models, the central limit theorem, statistical inference, estimation, hypothesis tests and analysis of variance.

Consider the following example problem:

> A machine makes lock washers. It is adjusted to make lock washers with an interior diameter of 5 mm. During production, an inspector checks the interior diameters of 10 lock washers to see whether the machine has slipped out of adjustment. The measures obtained were 5.20, 4.95, 5.73, 5.04, 5.17, 4.76, 4.84, 5.60, 5.85, and 5.16 mm. Do these results indicate that the machine has slipped out of adjustment and the average diameter of the lock washers is no longer 5 mm? (Use a 95% level of confidence and suppose that the interior diameter of the lock washers is normally distributed.)

This question could be briefly answered with a 'yes' or 'no'. However, to do so, a logical procedure should be applied. With the aim of illustrating this procedure we have designed a 16 questions scheme that helps students to understand the nuances required to solve the problem (cf. Appendix A for the complete list of questions associated to this kind of problem).

Although students can access on-line activities at any time and any place, some classes take place in a computer lab where students solve some of the problems with the assistance of teachers. These lab sessions are crucial to reduce the dropout rate of students with poor technological skills.

The method based on the fine division of problems could also be implemented in a traditional face-to-face format. However, if it is implemented without computer support, it has several drawbacks: (i) students lose the immediate feedback; (ii) teachers are unable to know precisely the timing and pace of work of each student; and (iii) the amount of time that teachers should invest in giving the appropriate feedback to a student and obtaining the information needed to determine the main learning difficulties is substantially greater. In fact, if the number of students is large, say more than a hundred, this method cannot be applied without the use of computers because it is very time consuming.

Furthermore, most on-line platforms provide teachers with detailed reports on students' activity. If problem schemes are correctly designed, these reports become an excellent tool to determine those concepts that pose important learning difficulties. Therefore, once the difficulties and misunderstandings are identified, teachers can easily adapt their lectures to the students' progress. The information included in on-line reports can also be used to classify students into groups depending on their need for guidance. By means of this classification, teachers can suggest specific activities and allocate appropriate resources to each group. As a result, the known tendency of teachers to overestimate their students' understanding is avoided [16]. Also, teachers can better assess the learning outcomes of the course, which can mainly be summarized as:

1. to be able to properly use statistical analysis techniques,
2. to apply this knowledge to solve engineering problems,
3. to solve problems effectively,
4. to apply logic and creative thinking,
5. to work autonomously and
6. to develop analysis and synthesis capabilities.

Thanks to the use of an on-line platform, time costs associated with students' evaluation are significantly reduced and teachers can invest more time in motivating students and emphasising the importance of the problems and the relevance of the results.

In addition to simplifying the teachers' work, web-based platforms are environments where students can learn in an individualised and flexible manner. Since, in our approach, mistakes are not penalised and feedback is provided immediately, errors are understood by students as opportunities to learn and their motivation increases. Students can face their misconceptions immediately and correct inaccuracies in their understanding. Moreover, the choice of a correct answer reinforces the student's learning process and allows him or her to realise that they are progressing properly.

2.2 Software Tools

Although there are several online homework delivery systems, such as the widely used WeBWorK platform [17–19], we initially implemented our approach by means of specially designed software called Statistics Self-learning Program (SSP); however, recently we have migrated to an off-the-shelf course management system called Moodle. In the following sections we provide the reader with some comments and screenshots of both tools. Section 2.2.1 is devoted to the SSP tool whilst Section 2.2.2 concentrates on the implementation of our proposal using Moodle.

2.2.1 Statistics Self-learning Program

The Statistics Self-learning Program (SSP) was our first attempt to move from theory into practice and start testing our method with students on-line. As it was designed for Catalan students, the user interface is written in Catalan and the original name of the software is PAEST (*Programa d'Autoaprenentatge de l'ESTadística*), which translates into English as Statistics Self-learning Programme (it is accessible on the web at https://paest-deim.urv.cat/).

SSP is based on Drupal, an open-source software distributed under the GPL ('GNU General Public License'). Drupal is maintained and developed by a community of thousands of users and developers worldwide. It can be used as a Content Management Systems (CMS) to create blogs, collaborative authoring environments, forums, etc. Drupal, and by extension SSP, runs on a web server (e.g. Apache) that manages queries from users, uses a database (e.g. My-SQL) that stores all the users' and problems' information, and it is implemented in PHP.

Figure 1 shows a screen shot of SSP. After entering their *log-in* and *password* information, users can work with our software by selecting from the top-right menu problems grouped in several statistical areas (e.g. Analysis of variance, Hypothesis tests, Probability theory, etc.). Each problem, subdivided into many questions, is progressively displayed in the user's browser. Once a question is properly solved, the next question is displayed. After three wrong answers to the same question, the system automatically provides the user with the right solution and the next question is displayed.

SSP is used by many students studying for a variety of degrees. Unfortunately, the program is not connected to the students' central database of the university and it is only used for statistical courses. Thus, it has the following main shortcomings:

- First time users must ask for an account and must wait until they are allowed to access SSP. However, this is a minor problem as access can be granted to a whole group of students in a short amount of time. For example, the time needed to grant access to forty students is about fifteen minutes. Moreover, this problem could be solved in the near future if the university board approves the connection of SSP to the students' central database.
- Since SSP is still at a test stage, it occasionally has some undesired malfunctions. These malfunctions are usually fixed within one or two working days.

2.2.2 Moodle

The Statistics Self-learning Program described in the above section is in a test stage. With the aim of

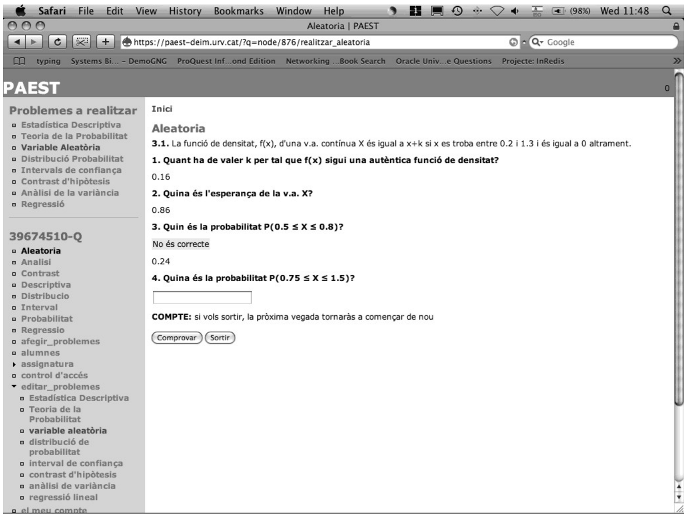

Fig. 1. Screen shot of SSP (in Catalan).

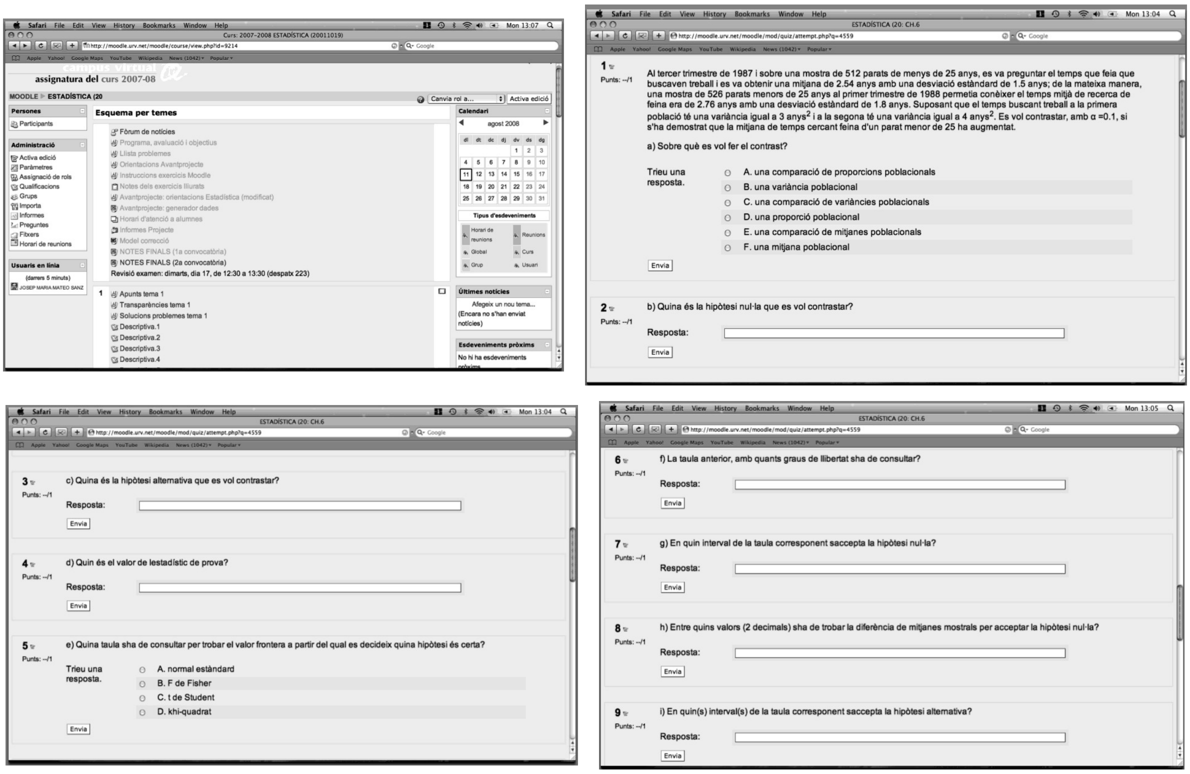

Fig. 2. Screen shots of the Moodle application (in Catalan). The top-left image shows the main screen of the application. The other screen shots show some sub-questions for a given statistical problem.

overcoming some of the SSP limitations, and to provide an alternative, we have developed a new implementation based on Moodle (see Figure 2 for some screen shots).

Most on-line learning platforms are based on Course Management Systems (CouMS)*. Course management systems provide web-based environments specifically designed to help instructors create on-line activities. Instructors can easily prepare and distribute materials, assignments and tests. It is also easy to foster collaborative learning by using tools such as discussion forums or blogs that are available in these environments. There are many examples of both commercial and free CouMS on the market (cf. [20] for a complete list of CouMS). Of the free systems, Moodle (Modular Object Oriented Developmental Learning Environment) is one of the most commonly used by learning communities worldwide. An exhaustive description of Moodle can be found in [21].

Moodle is the web learning environment that our institution, the Rovira i Virgili University

* We use the acronym CouMS to avoid confusion with CMS, which is used for Content Management Systems.

(URV), has chosen. So, teachers, whose courses need on-line support, are encouraged to use this tool, and they receive technical help and introductory courses if needed. This institutional support was the main reason for selecting Moodle as one of the software tools used to implement the method described in this paper. Since most of the courses offered by our university use Moodle, students are very familiar with its features. However, Moodle has some limitations that make the implementation of our method more complex.

The main advantages of Moodle can be summarised as follows.

- Moodle receives institutional support.
- Students are familiar with Moodle.
- URV students have automatic and easy access to the Moodle environment.
- Little time is needed to teach students how to work with Moodle.

It is worth noting that all these advantages are the result of institutional support to Moodle. On the other hand, the most important disadvantages can be summarised as follows.

- Various Moodle resources must be properly combined to split a problem into several short questions. Consequently, a substantial amount of time is needed to add a step by step problem in the Moodle interface.
- Students see all the short questions of a problem at the same time.
- It is not possible to choose a specific number of wrong answers before the right answer is revealed to the student.
- It is difficult to introduce random numbers in the statements of problems to make them different each time students try to solve them.

Although these shortcomings of Moodle are important, it has a long list of developers that contribute to its constant improvement; hence, we expect that some of these drawbacks will be overcome in the near future.

3. RESULTS AND DISCUSSION

We have analysed the influence of our method on the motivation and satisfaction of the students and on the dropout and success rates. Next, in Section 3.1 we explain the questionnaire that we have designed and the context in which it has been used. The results obtained are analysed in Section 3.2.

3.1 Design of the study

Our methodology has been tested in an introductory Statistics course taught at the Rovira i Virgili University in Catalonia (Spain). This 45-hour course lasts for 15 weeks and has been designed to fit the needs of students studying for different degrees. The course is divided into 30 hours of regular lectures and 15 hours of practical activities. The major topics of the course include descriptive statistics, linear regression, probability distribution functions, interval estimation and hypothesis testing. The course emphasises analysis and synthesis of data in practical problems without diminishing the importance of understanding the underlying theoretical concepts. The regular lectures are mainly devoted to helping students to understand concepts. However, it is known [22] that even when a concept is understood the inherent problem-solving procedure needs to be internalised to apply it successfully in practice. The proposed guided problem-based methodology has a key role in achieving this internalisation. We have used the guided problem-based learning methodology in several classes of this course over the last four years. However, the current study is the first rigorous attempt to assess the usefulness of our method to enhance the motivation/satisfaction of students. Hence, no comparative study of the students' satisfaction level before and after adopting the methodology is provided in the current study.

A questionnaire has been designed to obtain information about the students' satisfaction with the proposed method and to find inaccuracies in the structure of the guided problems. The questionnaire consists of twelve close-ended questions and one open-ended question that are divided into three sections. The first section briefly explores the knowledge that students have about the European Space for Higher Education (ESHE): it is important to determine whether students realise about the educational context in which they are immersed. The ability of students to interact with web-based learning environments is measured in the second section. Finally, the third section aims to analyse the attitude of the students towards our method. It is worth noting that the most relevant questions to the present research are included in the third section of the questionnaire (cf. Appendix B for the complete list of questions).

The questionnaire was distributed in the last day of the Spring semester of the academic year 2007–08. It was filled in by all students attending the class (note that although attending classes is recommended, it is not mandatory). There were no time limits to filling in the questionnaire. In addition, teachers explained the meaning of each question in the questionnaire in order to avoid ambiguities or misunderstandings. In order to obtain realistic answers the questionnaire was anonymous. Unfortunately, this anonymity prevents us from analysing the relationship between student satisfaction and student grades.

The sample for this study consisted of 133 students on an introductory course in statistics from four different degree programmes. There are six different classes, three for the Bachelor Degree in Computer Science and one for each of the three other degree programmes (i.e. Bachelor Degree in Mechanical Engineering, Bachelor Degree in Chemical Engineering and Degree in

Table 1. Sample features

Degree programme	Acronym	Year	Sample size
Bachelor Degree in Mechanical Eng.	BDME	First	42
Bachelor Degree in Chemical Eng.	BDCE	First	27
Bachelor Degree in Computer Science	BDCS	Second	52
Degree in Biotechnology	DB	Fourth	12

Table 2. Results of the homogeneity test

Question	p-value	Conclusion
Q1	5.42E-08	Heterogeneous
Q2	0.001	Heterogeneous
Q3	0.307	Homogeneous
Q4	0.155	Homogeneous
Q5	0.005	Heterogeneous
Q6	0.168	Homogeneous
Q7	0.002	Heterogeneous
Q8	0.077	Homogeneous
Q9	7.16E-05	Heterogeneous
Q10	1.63E-05	Heterogeneous
Q11	0.087	Homogeneous
Q12	0.092	Homogeneous

Biotechnology). The number of respondents in each degree and their course year are shown in Table 1. The course is taught by faculty from the Chemical Engineering and the Computer Science Departments. Specifically, two instructors from the Computer Science Department teach the course for the Bachelor Degree in Computer Science and one instructor from the Chemical Engineering Department teaches the course for the other three degree programmes.

The course assessment was based on three exams organised as step-by-step problems accessible on-line, and one traditional exam on paper. Each exam carries 25% of the final mark. Questions in the traditional exam are particularly designed to assess the students' understanding of theoretical concepts.

3.2 Data Analysis

After gathering the data from the questionnaire, we aggregated them. This aggregation allows us to observe general trends in the answers to the questionnaire. In addition, to test whether the aggregated results are representative of all the studied degrees, we carried out a homogeneity analysis, which is reported in the next section (Section 3.2.1).

In the following sections we analyse the results in terms of students' knowledge of their learning context and on-line learning tools (Section 3.2.2), students' satisfaction (Section 3.2.3), and students' motivation (Section 3.2.4).

3.2.1 Analysis of homogeneity

Homogeneity tests are used to determine whether a set of results obtained from different groups or populations are similar. In our case, we apply a homogeneity test on the results obtained for each question of the questionnaire, and we observe the differences between the four studied degrees. The results of the homogeneity test for each question of the questionnaire are shown in Table 2. From these results, we can conclude that, given an error level $\alpha = 0.05$, the students of the studied degrees gave different answers to questions Q1, Q2, Q5, Q7, Q9 and Q10, but they answered the other questions homogeneously.

3.2.2 Students knowledge of the ESHE and on-line tools

Most students are not really aware of the educational framework in which they are immersed. As Table 3.Q1 shows, only 42 of the 133 respondents (32%) have some knowledge of the ESHE, and only two-thirds of the latter (20%) expect the ESHE to improve their learning process (cf. Table 3.Q2). A closer analysis of the data reveals that these two percentages tend to increase with the level of the course. Only 11% of students in the BDCE programme (first year) and 12% in the BDME programme (first year) consider that they know the main features of the ESHE. On the other hand, the percentage of students that have some knowledge about the ESHE rises to 44% for BDCS students (second year) and 92% in DB students (fourth year).

Since the questionnaire was given to the students at the end of the semester, we expected that most of them had already learned how to use our on-line guided problems and, by extension, they had achieved some proficiency in on-line learning environments. The results (see Table 3.Q3 and Table 3.Q4) confirm our expectations and show that 126 of the 133 respondents (95%) had some learning experience with an on-line platform and that our approach based on on-line guided problems was used by 119 students (89%) (Note that using our problem-based on-line software is not mandatory and students can choose whether or not to use it.)

3.2.3 Students' satisfaction

Our students believe that the proposed method helps them to better understand Statistics. As can be derived from the answers to question five, most of the students (86%) value the usefulness of the virtual guided problems. Furthermore, two-thirds of them (89 students) answered that the current methodology helps them improve their grades and, by extension, their understanding of statistical concepts. Flexibility is also seen as a relevant quality of the method by 66% of the respondents.

In agreement with the homogeneity analysis showed above there are slight differences in the

Table 3. Aggregated results of the questionnaire

Ans.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
a)	42 (32%)	26 (20%)	126 (95%)	6 (5%)	26 (19%)	119 (89%)	73 (55%)	8 (6%)	97 (73%)	10 (10%)	6 (5%)	87 (65%)
b)	91 (68%)	13 (10%)	7 (5%)	7 (5%)	27 (20%)	4 (3%)	39 (29%)	53 (40%)	27 (20%)	26 (27%)	108 (81%)	17 (13%)
c)		94 (71%)		112 (84%)	62 (46%)	10 (8%)	10 (8%)	72 (54%)	9 (7%)	61 (63%)	13 (10%)	29 (22%)
d)				8 (6%)	10 (7%)		11 (8%)				6 (5%)	
e)					6 (4%)							
f)					3 (2%)							

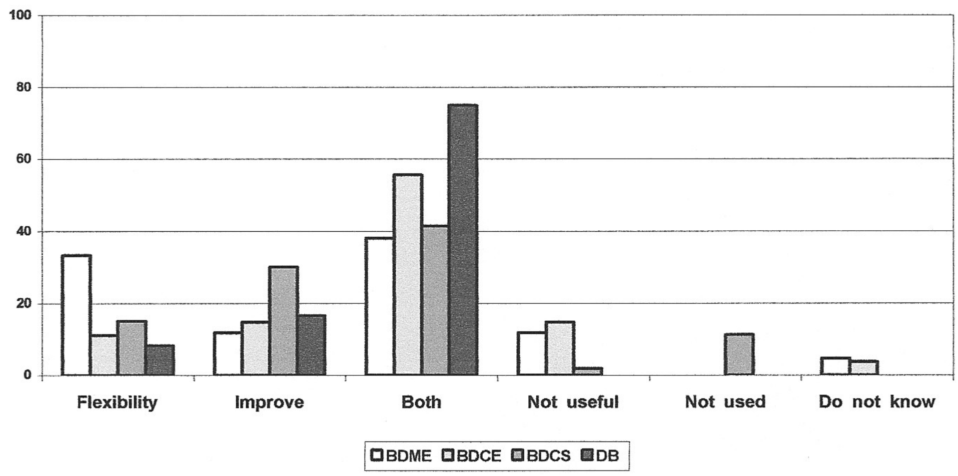

Fig. 3. Answers to question 5 (in percentage)

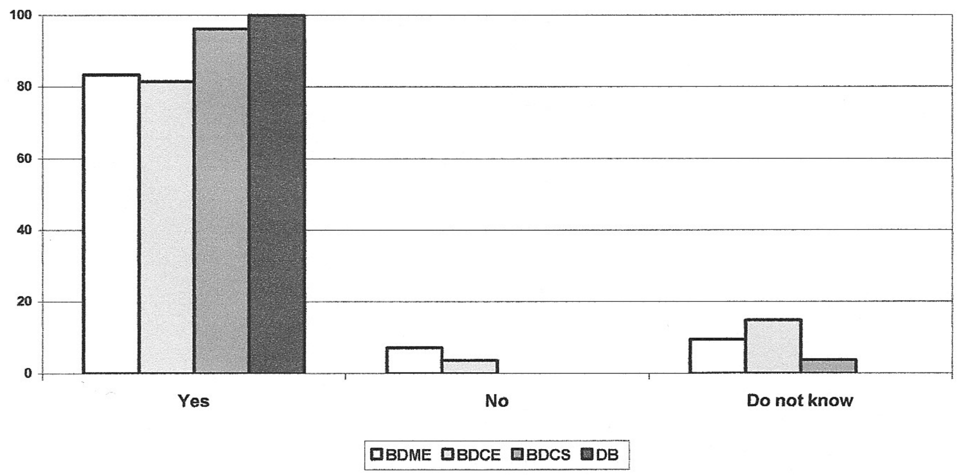

Fig. 4. Answers to question 6 (in percentage).

reasons why students believe that the methodology is useful (cf. Figure 3). The main differences between the studied degrees are: (i) BDME students emphasise the flexibility of our approach more than the other students, and (ii) a low percentage of BDCS students have not used our tool whilst all students in the other degrees have used it. A detailed analysis of the reasons for these differences is beyond the scope of this paper.

Students are very satisfied with our approach. Almost 90% of them believe that finely dividing problems into smaller questions help them improve (cf. Figure 4). Nevertheless, a significant percentage of students (37%) thought that the number of questions was not appropriate (cf. Table 3.Q7). Since most of them thought that the number of questions was excessive, especially BDME students (cf. Figure 5), future research

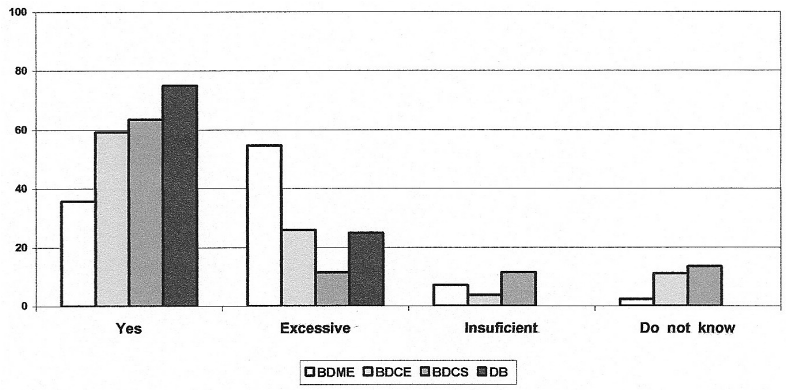

Fig. 5. Answers to question 7 (in percentage).

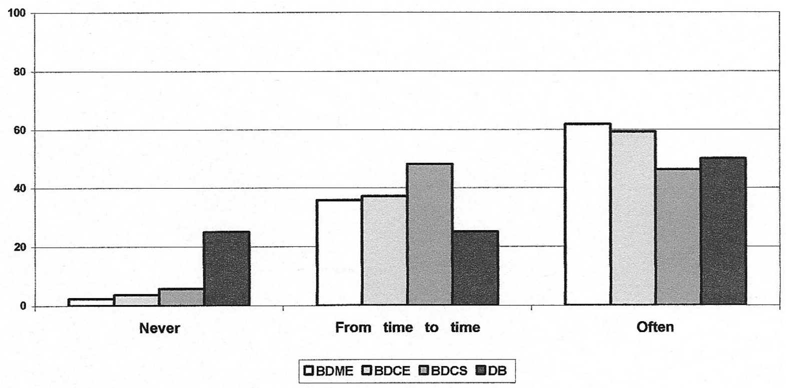

Fig. 6. Answers to question 8 (in percentage).

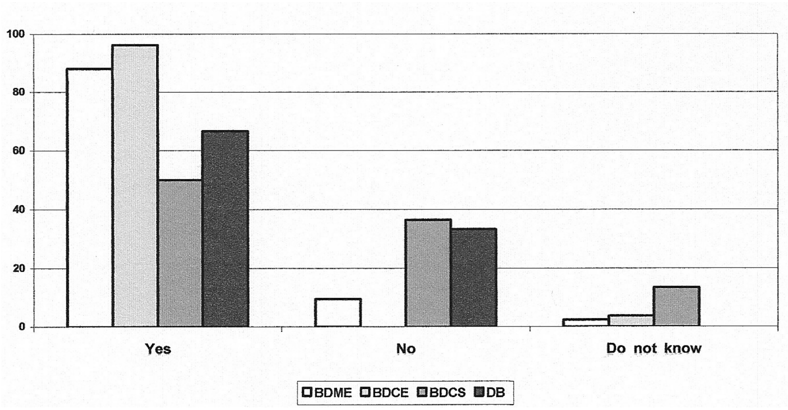

Fig. 7. Answers to question 9 (in percentage).

will be focused on estimating the optimal number of short questions that a guided problem should contain.

Our methodology has been welcomed by students (cf. Figure 6). Only 6% of them have never tried any of our on-line guided problems (cf. Table 3.Q8). Moreover, about half of them (54%) state that they use our guided problems regularly. This regularity was confirmed by the reports obtained from the Moodle log files.

The learning process associated with our on-line problem-based method is very short (cf. Figures 7 and 9). Table 3.Q9 show that the percentage of students requiring some help with solving their first problems is 73%, whilst only 10% (cf. Table 3.Q11) need help after this initial learning stage. These results indicate that students easily improve their ability to solve on-line problems as they move through the sequence of guided activities. Hence, it may be concluded that the guidance associated with the subdivision of problems is effective. It is worth noting that during the first exercises of each lesson BDME and BDCE students experienced more difficulties than the students on other degrees (cf. Figure 7). Table 3.Q10 shows that 73% of students who have problems in the early stages of

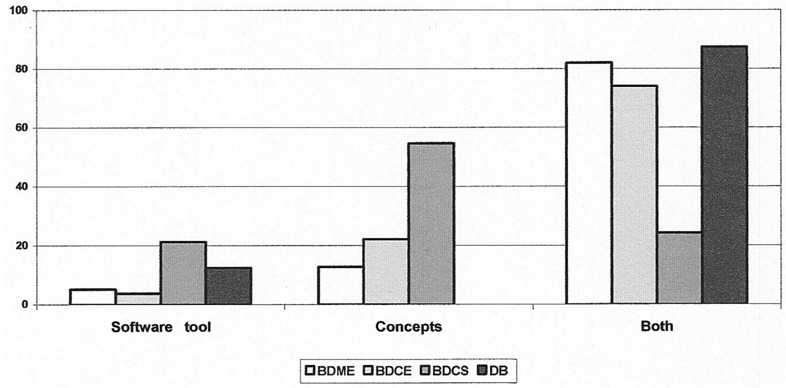

Fig. 8. Answers to question 10 (in percentage).

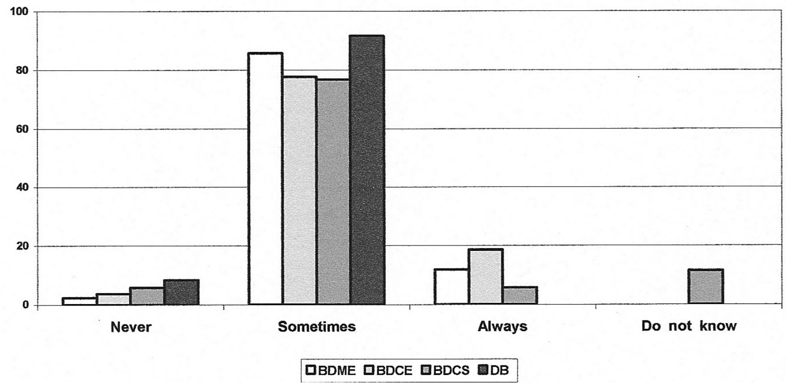

Fig. 9. Answers to question 11 (in percentage).

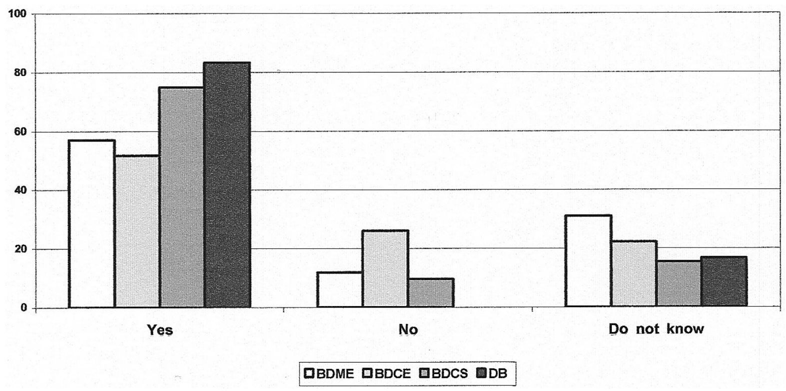

Fig. 10. Answers to question 12 (in percentage).

their learning process report that they have difficulties with the software tool. Consequently, we conclude that the initial technical instructions should be improved in the future in order to reduce this percentage. It is interesting to note that BDCS students have a different behaviour from the others (cf. Figure 8).

Figure 10 shows that most of the students highly appreciate the learning scenario developed in the current study; 65% (cf. Table 3.Q12) of them state that they would like our method to be used in other courses. However, the analysis of the students' answers to question 13 reveals that they would like to have some interactive help integrated in the software tool to prevent them from being stuck on a given question.

In conclusion, we believe that students are very satisfied with the proposed methodology but they ask for some improvements in the software tool (not in the methodology) to allow them to be more independent of teachers, even in the early stages of their learning process.

Students' motivation

The dropout rate has been studied in order to evaluate the effect of the current methodology on students' motivation. We have computed the dropout rate as the number of students who quit the course divided by the number of students initially enrolled. We have also studied the success rate as the number of students who succeeded in the

Table 4. Dropout and success results in the period 2004–2008

Academic year (First semester)	Total enrolment level	Total dropout level (rate%)	Total success level (rate%)
2004–05	227	97 (42.73%)	114 (50.22%)
2005–06	188	85 (45.21%)	76 (40.43%)
2006–07	179	65 (36.43%)	87 (48.60%)
2007–08	137	42 (30.65%)	73 (53.28%)

subject divided by the total number of students enrolled in the course.

The study was performed on students enrolled in the Computer Science programme. We analysed four semesters within the period 2004–2008. The proposed method was applied during the first semesters of academic years 2006–07 and 2007–08, whilst a traditional method was used in the first semesters of academic years 2004–05 and 2005–06. The instructors and curriculum were the same in the four analysed semesters. In all them, the enrolled students were distributed into three similarly sized groups. The facilities and the studied topics in each class session were the same in all groups. For the sake of equity, all students were gathered together during the assessment sessions.

The dropout and success results between 2004 and 2008 are shown in Table 4. It is apparent that although the use of our method has no effect in students' performance, it significantly decreases the dropout rates. Therefore we conclude that our method helps to improve students' motivation.

4. CONCLUSIONS

The new learning model impelled by the European Space for Higher Education fosters the appearance of new methodologies that concentrate on students and pay special attention to their proper progress. This paradigm shift from the teacher-centric methods to the student-centric ones implies that students work more on their own and teachers should supervise their progress individually. To cope with this change of paradigm, new methods that allow students to work on their own have to be developed. At the same time, these methods should help teachers to supervise the students' learning process.

In this paper, we have proposed a new method to pose statistical problems to students using b-learning, so that students can work on their own and teachers can easily supervise their improvements. Our proposal is mainly based on two points.

1. Finely divide problems into many questions.
2. Use computer tools to move problems into the virtual world.

We have observed that our proposal has many benefits for students and teachers. Students can practise anywhere, anytime, thanks to the flexibility of our on-line platform. Moreover, the division of problems provides students with a clear structure that helps them to better understand statistical concepts. Also, instructors can easily obtain information about the learning process of students. This information allows teachers to focus on the concepts with which students have more difficulties.

Our study shows that students are very satisfied with our method and most of them would like to use it in other courses. This satisfaction clearly affects the dropout rate, which has significantly decreased in the courses in which our method has been applied. Although the success rate is not affected by the application of our method, we believe that the decrease of the dropout rate justifies its use.

In the near future we plan to add new features to the SSP tool and to the Moodle-based one. To do so, we will add some interactive help (e.g. pop-up menus, help buttons and the like), we will study the optimal number of questions that a given problem should have, and we will extend the collection of problems.

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APPENDIX A: SCHEME TO SOLVE OUR EXAMPLE PROBLEM

1. Choose which kind of hypothesis should be tested:
   (a) Mean's test
   (b) Proportion's test
   (c) Variance's test
   (d) Two means difference test
   (e) Two proportions difference test — Answer: a
2. What should be used for null hypothesis (H_0)? — Answer: $H_0 : \mu = 5$
3. What should be used for alternative hypothesis (H_1)? — Answer: $H_1 : \mu \neq 5$
4. Which is the value of the sample mean? — Answer: 5.23
5. Which is the value of the sample variance? — Answer: 0.1409
6. Which is the value of the sample test statistics? — Answer: 1.94
7. Which distribution should be used to determine the bounds of the critical region?
   (a) Standard normal distribution
   (b) Student's t distribution
   (c) χ^2 distribution
   (d) Fisher's F distribution — Answer: b
8. If it is the case, how many degrees of freedom should be used? — Answer: 9
9. What type of critical region should be used?
   (a) two-tailed
   (b) left-tailed
   (c) right-tailed — Answer: a

10. Which is the critical region of the test statistics? Answer: $(-\infty, -2.26)$–$(2.26, \infty)$
11. Which is the critical region of the sample mean? Answer: $(-\infty, 4.73)$–$(5.27, \infty)$
12. Which is the complementary of the critical region of the test statistics? Answer: $(-2.26\ , 2.26)$
13. Which is the complementary of the critical region of the sample mean? Answer: (4.73, 5.27)
14. Which is the attained p-value of the test? Answer: 0.0843
15. Should we reject H_0?
    (a) reject H_0
    (b) do not reject H_0 Answer: b
16. Is there enough evidence to conclude that the machine has slipped out of adjustment?
    (a) Yes
    (b) No Answer: b

APPENDIX B: STUDENTS' SATISFACTION SURVEY

Section I: Students knowledge of the ESHE

1. Do you know the essential components of the ESHE?
   (a) Yes
   (b) No
2. Do you think that the implementation of the educational model proposed by the ESHE will enhance the quality of your education?
   (a) Yes
   (b) No
   (c) Don't Know / No reply

Section II: Students' use of web-based learning environments

3. Have you ever used a web-based platform (e.g. Moodle) in your learning process?
   (a) Yes
   (b) No
4. Have you ever used a web-based platform (e.g. Moodle or SSP) in a statistics course?
   (a) Yes, but only to download course materials
   (b) Yes, but only to solve online exercises
   (c) Yes, to download course material and to solve online exercises
   (d) No

Section III: Students' attitude towards the guided-problem methodology

5. Do you think that the current method based on an on-line collection of guided problems is a useful tool to enhance your understanding of statistics? Why?
   (a) Yes because of its flexibility
   (b) Yes because it helps me to improve my grades
   (c) Yes for both reasons: flexibility and grades improvement
   (d) I think it is not a useful tool
   (e) I have never/hardly used it
   (f) Don't Know / No reply
6. Do you think that the division of the problems in shorter questions, which guide you to the solution, helps you to learn?
   (a) Yes
   (b) No
   (c) Don't Know / No reply
7. Do you think that the number of questions in each problem is appropriate?
   (a) Yes
   (b) No, I think it is excessive
   (c) No, I think it is insufficient
   (d) Don't Know / No reply

8. How often do you solve on-line problems by your own?
   (a) Never
   (b) Rarely
   (c) Quite often
9. After having studied the theory of a particular topic, do you need the instructor's help to solve the on-line activities related to that topic?
   (a) Yes (always/often)
   (b) No (hardly/never)
   (c) Don't Know / No reply
10. If you have answered yes to the previous question choose one of the following reasons:
   (a) I usually have difficulties using this software tool
   (b) I usually have difficulties understanding the related concepts
   (c) I usually have difficulties in both the use of the software tool and the understanding of the related concepts
11. Once you have carried out some online activities related to a particular topic, do you need the instructor's help to solve the next ones?
   (a) Never
   (b) Just in specific questions
   (c) Always
   (d) Don't Know / No reply
12. Would you like the present method, based on on-line refined problems, to be extended to other courses?
   (a) Yes
   (b) No
   (c) Don't Know / No reply
13. If you have comments or suggestions that you would like to add to improve the course methodology please write them down here.

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