Abstract

Purpose: This paper describes the activities designed and conducted with Primary School, Secondary School and University students to study the integration of alternative assessment and self-assessment online tools in Mathematics courses using iTest. iTest is an educational software tool born to support the continuous evaluation system promoted by the European Space for Higher Education (ESHE).

Research Methodology: To cyclically design, implement and analyze the results of the activities we followed a Design based Research methodology which also facilitates the collaboration between researchers and teachers.

Findings and practical implications: Students and professors involved in the activities had positive attitudes towards the practical use of the tool. It was detected that iTest offers a good testing tool for units that focus on skills and procedural development as well as for units that are problem-based and require visualization and manipulation of the geometric representation.

Value: iTest has been found to be an appropriate complementary software for evaluation in the ESHE. After all the experiences described in this paper, it is now possible to begin the design of a Virtual Learning Environment for Mathematics implementing iTest as the assessment and self-assessment tool.

Key words: online assessment, online self-assessment, assessment in Mathematics, teaching and learning of Mathematics, Design based Research, European Space for Higher Education.

1 Introduction

Assessment is a crucial issue in the teaching and learning of Mathematics at all levels of education. One of the most important challenges facing Mathematics educators is to devise and successfully implement new assessment strategies for their use in the 21st century classroom [15, 14]. This challenge is especially important in European universities, where new student-focused methods for teaching and learning have been developed by such entities as the European Space for Higher Education (ESHE) [2, 7]. New teaching methods necessitate new tools for continuous assessment and self-assessment [9, 17].

In many universities, time constrains, curriculum restrictions and professors’ lack of experience prevent the use of new assessments tools. But the Internet has made possible new, interactive forms of teaching and learning, as well as new forms of assessment, or test-taking.

Our research team HEOL (from the Spanish expression Herramientas de Evaluación On Line) is composed of professors from the Computer Science department at CES Felipe II, the Universidad Complutense de Madrid campus in Aranjuez (Spain), and from the SIP department of the main campus in Madrid (Spain). We decided to take advantage of the Internet’s potential and began experimenting with online tests in our classrooms. HEOL developed a new online assessment tool, called iTest, initially oriented to evaluate undergraduate students in Mathematics courses. After pilot testing this software in 2007, we have been using it with our students since the 2007-08 academic year trying to incorporate iTest as a complementary evaluation system in the new methodology promoted by the ESHE.

Since our students and professors initial response was so positive towards the use of iTest, we are currently expanding the use of this software to other courses from our Com-
computer Science department (such as Computer Architectures, Robotics, C++ programming and Data structures) as well as from other departments in our institution (like Fine Arts, Foreign Languages, Tourism, Economics and Communication and Journalism).

However, after the first pilot tests with undergraduate Mathematics students, it was found that many of them had great difficulty on understanding word problems, especially when they had to distinguish or graphically represent the provided data. Students also tend to rush when the tests are administered online (by a computer), spending less time than planned by the teacher in completing the questionnaires. In parallel to the University pilots, we began a study with students from Primary and Secondary schools adapting the user interface and user interaction process of iTest for younger students. In particular, we are designing pilot activities in Mathematics for primary school students trying to help them overcome the difficulties just mentioned (see Figure 1).

It is an established fact [5, 16] that teachers tend to employ methods of teaching derived from their own experiences as students. Hence, they commonly use conventional paper-and-pencil examinations to assess student learning. After our positive experiences with iTest and university professors, it seemed natural and reasonable to share iTest with primary and secondary school teachers. To facilitate and to promote the adoption of iTest, we administered several in-service teacher training seminars and help the participants to put iTest into practice with their students.

On the university level, as we will describe in Section 3, we used our software as part of the continuous evaluation methodology to complement regular paper-and-pencil exams, homework assignments and oral presentations following the ESHE methodology in pilot groups of college freshman. With traditional groups we have prepared online tests to allow students to self-evaluate their progress in the course. This helped them to prepare for a final exam in which the first part was administered through iTest (50% of the total score).

Our activities were conceived to address the following questions, which we view as a point of departure for the initial study presented in this article:

1. What are the factors that impede or facilitate the implementation of online assessment tools in the classroom?
2. How are the students’ marks on the online examinations compared to their results on paper-and-pencil tests covering the same topics? If there are significant differences, what are the factors that cause these differences?
3. What are the students’ views of being online assessed or online self-assessed?
4. What are the teacher’s views of using online assessment tools with their students?

This article presents our first findings and describes the Design based [6, 20] research methodology we are currently using to design, implement and analyze the results of activities (sometimes developing new features for iTest) in the area of Mathematics facilitating the collaboration between researchers and teachers.

The undergraduate students involved in the tests described here were all registered at CES Felipe II, the campus of the Universidad Complutense de Madrid located in the city of Aranjuez, 35 miles south of Madrid, Spain.

The rest of the paper is organized as follows: First we include a description of the features of iTest, then we describe the activities implemented with undergraduate students including a short description of the research methodology. We also detail the experiences we have conducted with Mathematics students in local public primary and secondary schools. Our collaboration with their teachers yielded some insightful comments about our in-service training seminars. We conclude the article by recapitulating our findings and pointing out future work.

2 Description of the tool

There are many tools that deal with graded quizzes, such as Hot Potatoes [3], and there are also complete e-learning platforms used in academia, such as Moodle [8]. These platforms usually have modules to generate tests for the students, though they use different formats. They are limited, however, by the fact that mathematical formulas and graphs...
of functions cannot be easily integrated, accessed, visualized or stored in databases. Although there are commercial plugins (e.g. WIRIS [4]) to include math content in Moodle, the use of the whole platform is complex and sometimes frustrating. Teachers often are discouraged because they do not have time to learn how to use e-learning platforms with so many features, and without personalized and constant technical support. For all these reasons, our HEOL research group designed, developed and implemented iTest.

In a few words, iTest is a web application that allows instructors to configure multiple choice exams wherein questions are randomly selected from the database according to the established configuration. Students take exams using iTest and receive their grades automatically after finishing the test. Through an intuitive interface, iTest allows professors to easily include mathematical formulas and (plane) graphs of functions in the body of questions and answers through a math editor supporting LATEX type code. It is also possible to insert multimedia files (e.g. images, audios, animations and GeoGebra files) and links to YouTube videos into the body of questions, which allows for greater interactivity with the students. As well, iTest allows students to review their graded exams, which has proved to be an extremely useful form of self-assessment. The teachers may include comments on each question that will be displayed on the review. These two aspects (interactivity and review) enable exploration, which is crucial to formative assessment [9].

iTest automatically collects various statistics about the results of each examination for the instructor, and this has been proved a source of valuable feedback that is hard to obtain from paper-and-pencil exams. This feedback allows the teachers to make the appropriate adjustments to address students’ learning problems.

Every new tool in online assessment should provide some added value to the current state of the art. In this way, iTest contributes in two different aspects. First, it offers capabilities to create and edit mathematical formulas, graphs of functions and Venn diagrams in LATEX-style format that enables the inclusion of mathematical expressions in questions and answers. This feature is particularly useful because it avoids the use of another tool to generate an image representing the formulas. And second, it is also possible for the instructor, through a very intuitive interface, to embed multimedia contents such as dynamic geometry GeoGebra files [11], Flash animations, image or audio files and links to YouTube videos in the question content. The answer content may also include multimedia files, and both questions and answers may be enhanced with font colors and simple font styles like bold, underline and italic.

In order to illustrate these features, Figure 2 shows an example of question including GeoGebra content [12], while Figure 3 shows the interface for adding a question. This latter figure shows the complete set of operations for editing the question content, Math editor, multimedia files, answers, etc., all of them integrated in the same interface, but taking care of being user friendly.

In terms of data organization and access privileges, iTest provides support for two main types of users, named teachers and students, which are grouped into institutions, all of them registered on the same database. In this way, it is possible for teacher users to share any number of their authored questions by just applying public visibility to them. This is a very innovative and important factor that allows instructors, even from different institutions, to collaborate creating a common repository not only formed by multimedia content, but also by exam questions.

Then, teachers can author questions, attach them to a topic in the syllabus, and state their level of difficulty. These
parameters are relevant because they allow the teacher to control, if needed, the random generation of questions by fixing, for an exam configuration, the number of questions to be selected for each topic and level of difficulty.

A teacher user may also define a list of topics for the course, work with questions, manage exams, register students, view the grades of any student, and analyze statistics.

In addition, teachers may obtain for each exam the following statistical information: attendance and passing rates, and minimum, maximum, mean, median and standard deviation values for both the obtained grades and the time employed to solve the exam. The tool also provides percentages of correct, incorrect and non-answered questions.

A student user can take exams previously configured by the teacher of the course, and also review the taken exams. The questions for each student exam are randomly selected depending on the configuration defined by the teacher. Once the students have finished their exams, their scores can immediately be seen on the screen (some students prefer to check their grades later). Comments included by the teacher in each question are shown in the revision. These comments are extremely useful for self-assessment.

Figure 4. iTest software architecture

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Another aspect of iTest is that it aims at being compatible with other Learning Management Systems (LMS): iTest was designed as a service that could be integrated in other e-learning systems. In terms of implementation, iTest was developed as a Java application based on a MVC (model-view-controller) architecture where the database support complies with the SQL standard. Since it was developed according to MVC paradigm, any LMS could integrate iTest through the API provided by the model layer. Figure 4 shows the software architecture that implements the MVC pattern. Due to our needs, the view (presentation) and controller (business) layers of iTest were designed using J2EE technologies (JSP and servlets) in order to produce a dynamic web application. As a result, iTest combines web technologies such as AJAX and MathML [1], server-side Java technology (J2EE under a Spring framework) and database access (Ibatis over MySQL at the persistency layer), offering a web tool for online exams where contents and support services are interoperable, and compatible with the so-called Web 2.0.

3 Research methodology and activities with undergraduate students

There was a strong need in our department of a software like iTest to help professors and students to assess quickly and easily the teaching and learning process [13]. In their first year in college, students are not accustomed to the evaluation method traditionally used at Spanish universities where only a final exam at the end of each semester is administered in abstract courses. As we mentioned above, at the beginning of the year 2007 we decided to design, implement and pilot test an online evaluation tool with a group of Calculus students. Since this pilot experience was positive for the students and professors involved, we decided to dedicate a deeper look to the study of the integration of iTest in Mathematics undergraduate courses.

3.1 Research methodology: Design Based Research

To formalize this study, it was decided to use as research strategy the Design based Research methodology [6, 20, 18]. Design experiments were developed as a way to carry out formative research to test and refine educational designs based on principles derived from prior research. This methodology has an action-research oriented perspective which allows the continuous refinement of the proposed model. In our proposed model researchers work together with educators and must try to change things. We have considered the following four stages after T. C Reeves:

1. Analysis of the assessment problem in Mathematics undergraduate courses by researchers (who are also professors involved in the tests) and teachers in collaboration. We considered the new teaching and learning philosophy promoted by the European Space for Higher Education. We also took into account students background from high school.

2. Development of solutions considering previous experiences and integrating new technologies. After pilot testing a beta version of iTest in 2007, we designed
and implemented a more complete stable version of the tool. In this stage we also designed materials (including multimedia) for the activities in collaboration with the professors involved in the tests. The tests designed considered questions with different levels of difficulty trying to address generalized problems in each subject.

3. Cycles of testing and refining the proposed solutions in practice. These cycles were carried out every academic year in different Mathematics courses. As a consequence of these cycles, we detected the need of more features that we have implemented while the tests where designed and conducted.

4. Reflection (after each cycle) to produce design principles and enhance solution implementation. We have thought of various ways of administering the tests, some times at computer labs, some times at home, and some times with several parts where students were accumulating scores to the final grade.

3.2 Assessment activities with undergraduate students

During the 2007-08 academic year we used iTest at least once in all the Mathematics courses. In Figure 5 we summarize the results of these first tests. The average grade obtained by the students is represented over a total of 100 points in the first column for each subject. In the second column we represent the percentage of the average time students spent to complete an exam over the total time length configured by the professor. In the third column the percentage of students attending the tests over the total number of registered students is included, and finally, in the last column, we represent the passing rate (over the students attending the tests). It was not mandatory for the students to take the tests and some of the tests were taken by the students at our computer laboratories with teacher supervision and others were taken at home from their personal computers. The passing rate was not higher when tests were taken at home, in fact, the grade distribution of the online tests taken voluntarily without supervision was the same as the grade distribution obtained in the supervised paper-and-pencil final exam.

During the 2008-2009 academic year (see Figure 6), iTest has been used by all Math professors in our department as a support tool for the continuous evaluation methodology adapting to the ESHE. In all the courses at least one midterm exam was configured with iTest, and the performances on these tests represented between 20% and 40% of the final grade. Of course, regular paper-and-pencil examinations, as well as group presentations and homework assignments were students often had to use specific mathematical software were also considered. It is clear that multiple choice tests should not be considered as a unique assessment strategy especially when it is important to see how students work with proof reasoning. It is worth mentioning that in the Calculus course every student who did well on the online exams, passed the course, and only three students (12% of the students attending the course) passed the course having failed the exams with iTest. This results lead us to believe that there is no significant difference on students performance regarding the assessment model (i.e. online or paper-and-pencil) in concordance to the work done by Engelbrecht and Harding [10] and Sandene et al. [19]. Figure 7 shows how the percentage of students taking the online exams is slowly decreasing with time, a generalized problem in our classrooms. It should be taken into account that most of the questions and exam configurations were the same for the past 3 academic years but some variations on students performances can be detected from one year to another.

iTest has been also used as a self-assessment tool with a group of sophomore Statistics students in 2008-09. In this case, six tests covering different topics were prepared during the semester and students took them voluntarily. Some of them even asked for a reactivation of the same tests several times, as a way to practice more. Bear in mind that a student may obtain different exams with the same configuration parameters thanks to the randomness generation of the exams. The final examination in this course had two parts counting 50 points each. The first part was administered with iTest based on the exercises from the partial training tests. The average grade in this first part was very high (31.5/50) compared to the average score obtained by the students in the second part (17.4/50) where they had to solve five problems. This means in particular, that previous training with iTest improved students performances in the multiple choice part of the final exam as it was expected. It is worth mentioning here that in general, in Mathematics courses at college level, it is harder for students to write complete answers for an exercise than to go over a multiple-choice test.

Through our experience using iTest with undergraduates in Math courses in the past academic years, we have detected that our software offers a good testing tool for units that focus on skills and procedural development (Algebra, Differentiation and Integration methods and Logic) as well as for units that are problem-based and required visualization (use of graphs) and manipulation of the geometric representation (use of GeoGebra files) such as definite integrals and probability distributions. So iTest facilitates formative assessment in those areas.

Even though it was found that many students had great difficulty understanding word problems and looking for the relevant data in the question statement, at college level we have not detected (personal nor technical) impediments for
the use of *iTest*. Students and professors involved in the activities had positive attitudes towards the practical use of the tool. Since all of our students had Internet connection at home, taking and revising tests at home was always a possibility. It is important to mention here that our students had also access to the computer labs when necessary.

We have noticed through questionnaires and personal interviews that students like this combination of evaluation methods, they feel less anxious during the tests and they really like getting their grades and revision automatically. Students find *iTest* a great educational software for self-assessment.

The professors remarks about *iTest* have also been collected through different questionnaires. We have realized that the first time *iTest* was used, it was very time consuming for them, since they had to design and upload in the data base all the questions, including the multimedia files when required, but once they had a reasonable amount of questions per topic, the use of *iTest* was extremely easy and convenient. They all found very helpful the math editor, the possibility of including images and GeoGebra files and the statistics of the results automatically provided by *iTest*. Percentages of failure and success for every question that has appear in an exam, were extremely useful, not only to help the teacher resolve generalized problems in time, but also as part of the reflection stages in the research methodology proposed.

## 4 *iTest* in-service teacher training

As it has been discussed in the Introduction, despite the great amount of e-learning software available for Primary and Secondary school teachers, it is very hard for them to use those applications in a real classroom without close supervision and permanent personalized assistance [5, 9]. To overcome this drawback, our group decided to provide the teachers interested in using *iTest* with yearly training seminars, aided by self-learning materials and other monitoring activities. They should be the driving force behind overcoming the initial mistrusts to the use of a new and unknown e-learning tool in the classroom. The next lines summarize how the establishement of these formative activities, which involved a close and permanent contact with the *iTest* developers, was the key to put *iTest* into practice.

The first *iTest* in-service training seminar for Secondary school instructors was established in 2007. Around 20 teachers attended the course. It was divided into different sessions, where the *iTest* management basics were shown and practiced: question and answers preparation, multimedia files inclusion, exam configuration, analysis of exam results, etc. As all participants were satisfied and they really appreciated our close monitorization, in the 2007-08 academic year the *iTest* course was given again, having roughly
the same attendance. We also started a second iTest seminar for pre-school teachers, where the use of the special kid interface and multimedia material preparation were the principal activities. Several Flash animations and audios were developed jointly by teachers and HEOL interns. In the 2008-09 academic year we facilitated one seminar, this time for Primary school teachers. We also started with a new approach: in-service training based on self-learning (e-learning) teacher groups. As an additional help to all of them, we created an iTest website (http://www.itest.es/), which includes a detailed application manual. In addition, a video presenting the main aspects of our tool to help the newbie teacher user was uploaded. It is complemented by a student user demo allowing everybody to enter iTest, make exams, answer questions, navigate through them and once finished get the mark and look up the exam review as any student does. The website also contains specific sections for multimedia sample materials, a description of the present and past activities related to iTest in-service training and all the active seminars agenda. A forum was also added, where all the users may share their experiences and ask other users their doubts concerning the tool or its use in their classrooms.

During that 2008-09 academic year we also worked with Primary school Math students. In particular, we carried out an experiment with K-5 students (10-11 years old) where a total of 40 students are participating. We planned to continue the experiment during two complete academic years with the same students. One of the main goals of this activity is to gather quantitative data to answer one of the questions arisen in the Introduction, making a comparative analysis of the results obtained by the K-5 students in the regular paper-and-pencil Math exams and in online multiple choice tests covering exactly the same topics and adapted to iTest from the traditional exams. The online tests are always taken in the school computer laboratory and in the same week as the paper-and-pencil exam is done. This was possible thanks to the involvement of the Informatics instructor (also in charge of the school computer lab) who voluntarily administered the tests during his weekly hour class.

Finally, in the 2009-10 academic year we have continued our training activities offering two seminars, one for Primary and the other for Secondary school teachers. In these two seminars we have combined conventional guided sessions and self-learning activities with iTest. As in past editions, each course attendance ranged from 15 to 20 attendees in all sessions. All these training activities have been greatly welcomed by the participants, encouraging us to continue with the in-service training seminars in the future.

During the in-service teacher training seminars, several activities were proposed, designed and implemented with students. For example, a group of teachers from the Math Department in one of the local public high schools, proposed the idea of preparing a math contest for their K7-8 students (12-14 years old). Since they wanted all their 300 students to participate, they decided to use iTest in a first phase of the contest. Individual and groups scores were considered. The prize of the contest was a trip to a science museum for the whole group that won the contest. Since it was very important to help your group, students felt the need to improve their personal performances, given that all individual performances would be added to the group final score. Once the first phase was completed, the teachers informed the students about their results. The best five students of each group participated then in the second and final phase of the contest. This phase took place in one of our university auditoriums with a host. Participants started with the group scores they had accumulated in phase one. The host was asking a given question to all groups of students who had a fixed time to get the answer. They could ask for help to their classmates sitting at the stands once. It was hard to coordinate all the people involved in the contest but it was a great experience for everybody. Teachers noticed that students performances at the end of the year were much better thanks to this motivational activity.

We are also observing the students closely and continuously, trying to detect possible changes in their attitudes towards Mathematics when using iTest, with the aim of quantifying any increase in motivation, a better concentration on each question or in the visualization in Geometry questions, a decrease in nervousness while taking exams, etc.

With regard to the last question stated in Section 1, as it was aforementioned, we have asked to all the teachers participating in each of our seminars to voluntary answer a questionnaire with standardized answers about the formation received. Such literature-based questions asked their opinions about the clarity and suitability of the seminar contents and teaching methodology, and as well as their degree of satisfaction about both the course goals achievement and the iTest overall experience. More than 90% of those polled think the course is useful or very useful for them, scoring 4.4 over 5 on average. It is interesting to emphasize how though most of the teachers show poor to very poor former experiences with ITs, they find no difficulties related to the iTest usability. In addition, teachers think that despite it can be very time consuming at the beginning, iTest is as a very useful, powerful and user-friendly tool which facilitates sharing materials and question banks among departments or Schools. And since parents are able to join their children when reviewing their graded and commented tests, they stress how iTest helps to create a bridge between schools and families. This is particularly important at the Primary and Secondary school, making report children’s learning progress to parents easier.

But there are always some obstacles and impediments
to overcome when trying to adapt and to spread new technology-based evaluation methods as iTest. The most relevant are related to the fact that many Primary schools in Spain still have poor or small computer labs, generally with nonexistent or very limited technical support. This fact often makes the teacher also responsible for the lab support and maintenance. If we want to encourage the use of these and other new methodologies in the classrooms, the responsible authorities should work together to eliminate such hitch in the near future.

5 Summary and conclusions

iTest is an online evaluation tool fully developed by a group of professors from the Computer Science department of the Universidad Complutense de Madrid. It is a web application that allows teachers to configure multiple choice quizzes, where questions and answers are randomly selected from the teacher’s question bank. Mathematical formulas and graphs are typed in the body of questions and answers through a very intuitive interface. Interaction with students is provided by the inclusion of images, audios, GeoGebra and other multimedia files. Once the students take their quizzes, they are automatically graded and the students have instant access to the graded-exam revision, this has proved to enable formative assessment.

Regarding future work, it is clear that our activities hitherto done have motivated a more intense use of iTest as an assessment and self-assessment tool in order to find more complete and accurate answers to the questions leading our research. New evaluation strategies will also be studied, as the possibility of performing diagnostic tests in the first weeks of the semester to assist the identification of pupils that may require extra support.

Besides and more in the long term, some work needs to be done to adapt iTest to younger students in order to systematize its practical use in the classroom. We believe that iTest could be used to develop a virtual learning environment for dynamic geometry using GeoGebra and customizing the help menus for each student depending on their answers to the questionnaires. In such virtual learning environment for dynamic geometry, primary and secondary school students will hopefully acquire strategies that will allow them to overcome the difficulties encountered by undergraduate students in Mathematics courses.

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