Improving Student Results in a Statics Course using a Computer-based Training and Assessment System

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Abstract: **One of the main causes of desertion in engineering programs is the poor student academic performance in basic courses. One of these courses is Statics, which is taught at the undergraduate level. Between 2009 and 2011 about 30% of students did not get a satisfactory grade to pass the course and a high percentage of these students deserted from their engineering program at EAFIT University.**

The evolution of computer systems and the Internet progress have enabled educators to develop software to support teaching and learning processes. For instance, educational software like E-learning platforms now allow teachers and students to interact through collaborative and friendly environments that can result in improvement on student learning outcomes and therefore improvement in their final results. Various learning tools based on problem-based learning approaches have been developed for the Statics area. These systems usually pose problems for students to solve; however, the problems usually used to evaluate and certify student knowledge are different from those used by the students during their training process. This is aimed at focusing students' attention to the use of analytical skills instead of memorizing processes.

This paper describes the results of using a computer system to support training and assessment processes to convey concepts related to a Statics course using an existing open source tool and implementing a dynamic assessment generation scheme (i.e., generation of multiple versions of the same problem using algorithms with variables). This system has been used in the Statics courses during two academic periods in 2012 involving the participation of 400 students. The results of this experiment are compared with performance results of students from previous years who used traditional practice and assessment methods such as solving tasks in conventional paper and pencil tests. Results have had a positive impact in student grades and retention.

Keywords: computer systems, desertion, engineering, reprobation, training and assessment processes

I. INTRODUCTION

One of the main causes of desertion in engineering programs at universities is the poor performance of students in basic courses [1, 2, 3]. One of these courses is Statics, which is taught in the following undergraduate programs at EAFIT University: Mechanical, Civil and Production Engineering. From 2009 to 2011, about 30% of students did not get a satisfactory grade at the end of the Statics course and a high percentage of these students deserted from their engineering program.

Researchers [2, 3, 4, 5] have identified and discussed some causes of learning difficulty in some basic courses such as Statics and various solutions have been proposed to make the learning process more effective and motivating. One of the causes for students' failure and subsequent drop out is attributed to the misalignment between the elements involved in the process of training and evaluation systems; these elements are organized differently by teachers and students [6]. From the point of view of the teacher, first (s)he defines the learning objectives and then (s)he defines the process of planning instruction, selecting resources and activities and finally planning the evaluation. From the point of view of students, the assessment is the starting point of learning process and according to their beliefs, they plan their learning activities.

An alternative to achieve align training processes and assessment processes consists of linking both processes so the students find useful to make training efforts to achieve good results in the evaluation. This can be supported by the use of computerized assessment systems that help students in their preparation while measuring their level of knowledge on the subject.

This paper describes the result of using an online assessment system [7] to support training and evaluation processes. This system was implemented using open source tools. It implements a dynamic schema of assessment generation. The rest of this paper is organized as follows: section 2 defines the process of training and evaluation implemented in the system, section 3 describes computer evaluation systems, section 4 presents the implementation of an automatic task generation system, section 5 describes the

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study, section 6 reports of the results. Conclusions are presented in section 7.

II. Training and Evaluation Processes

The subject of Statics has a wide variety of text books [8, 9, 10, 11] which are the main tools that teachers use in preparing lessons and assessments, and for the students in preparing their learning plans.

A number of workshops have been designed to help student focus on learning the concepts rather than memorizing solutions to particular problems. However, sometimes there is no a good alignment between the assessments designed by the teacher and the activities the students do to get prepared for these assessments, which results in high course failure rates. This problem can be addressed by implementing a dynamic assessment approach [12, 13].

A dynamic assessment system that implements automatic generation of tasks has been implemented to help students to improve their performance on the Statics course [7]. This system offers tasks on relevant topics to be used for students in their preparation. These practice tasks have equivalent difficulty levels but with different contexts and variables those tasks are included in the teacher designed tests. This way students can be assigned different types of problems for a particular test.

By changing task parameters, the system can generate countless tests for students to practice. Thus, students have more opportunities to improve their conceptual and procedural knowledge on the subject.

III. Computer-based Evaluation systems

Computer automated assessment (e-assessment) [14] has been used in contexts such as professional certifications [15], certification tests of general knowledge [16], language testing [17], online courses [18], among others. These assessments can be administered by E-learning platforms [19], which are computer systems that have modules for managing administrative and academic tracking [20]. E-Learning platforms allow user interaction with Internet content. Platforms such as Moodle, Dokeos, Blackboard, Chamilo [21, 22, 23, 24] among other have transformed educational practices energizing the teaching-learning processes and supporting distance education schemes. The assessment modules on E-Learning platforms are implemented in standard formats that allow interoperability of assessments [25, 26]. Currently, great efforts are made to implement these systems in web-based schemes using technologies such as Cloud Computing [27].

The individualization of the assessments, which consists in assigning a different test to each student, has been implemented using computer systems. An example of this is Calculated Question Type [28], which includes variables that take different values each time the test is generated.

IV. Implementation of an automatic generation task system.

The system developed allows students to practice the concepts of the course by solving problems. The system generates a variety of problems modeled for each course topic using algorithms that generate different versions of these problems and deliver them to students using an E-learning platform. Students interact with the questions as part of workshops and teachers also use the system to assess student outcomes and track all interactions in the system.

The system generates questions automatically by assigning different values to variables involved, varying situations and solution strategies. The system also has an automatic plotter that creates images for particular problems.

The proposed evaluation system was designed to be used in different e-learning platforms. In the Statics course the system has been used with two E-learning platforms: Chamilo and Moodle.

Initially the system was designed to be used as an independent system. The generator produces the questions for tests; teachers import them into a bank of questions to be used in an LMS platform (see Figure 1). Currently a plugin that will automatically perform some of these test configuration processes is under development.

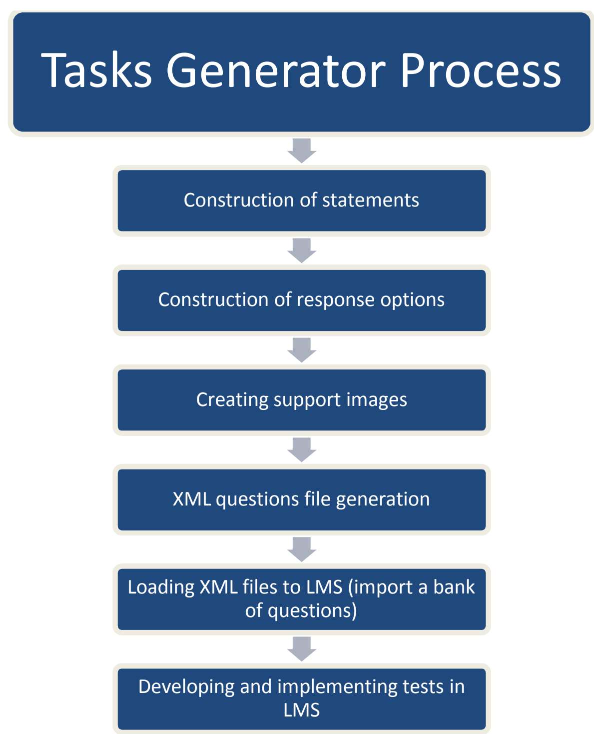

Fig. 1. Process of creation of a new test

Users are classified in three different groups: teachers, coordinators and students. Teachers are involved in various stages of the process, first the construction of the engine by providing input to the development team to design and implement problem solving algorithms, and also in the administration of test results submitted by the students through the system (see Figure 2).

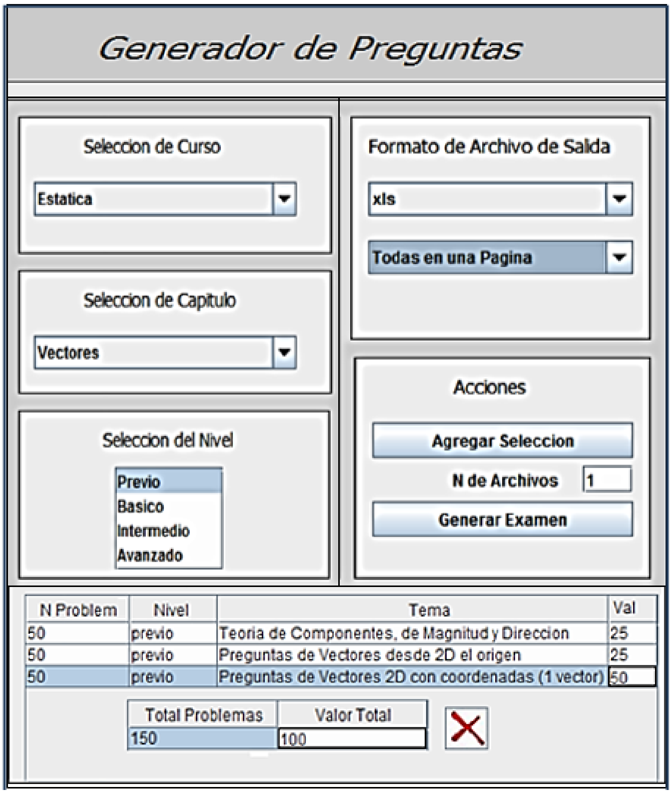

Fig. 2. Interfaces for coordinators and teachers to create a test.

Coordinators, with the help of teachers of the course, are responsible for pre-set tests; this means that they can change the parameters of an evaluation. Parameters available include: subjects, duration, date, difficulty level, and number of attempts (see Figure 3).

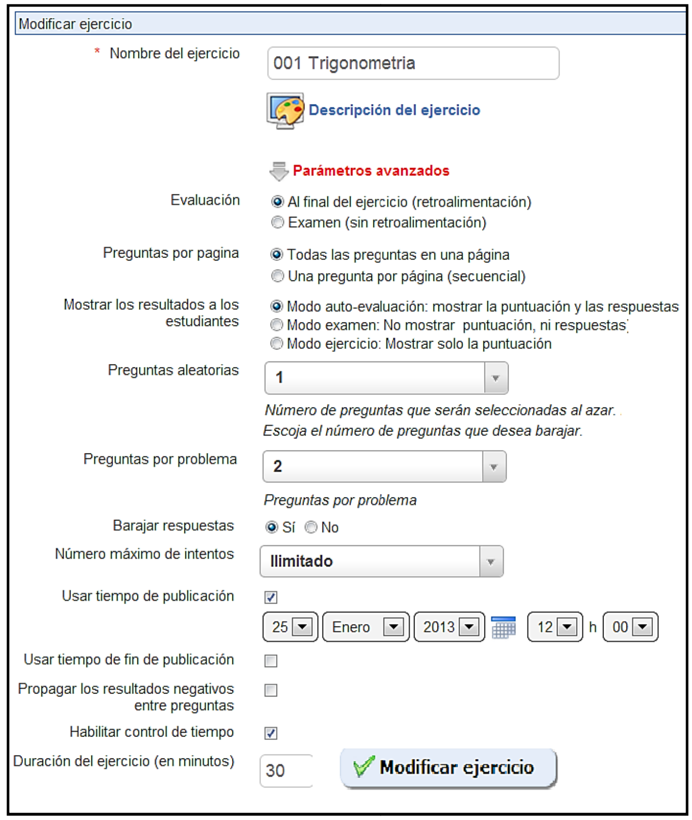

Fig. 3. Interfaces for coordinators and teachers to configure a test.

Students can interact with the system in two different ways. The first way is called training mode where students can select the topic and problem type therefore the system generates a test to practice. The second way is called evaluation mode, in which students answer previously configured tests created by coordinators and teachers (see Figure 4).

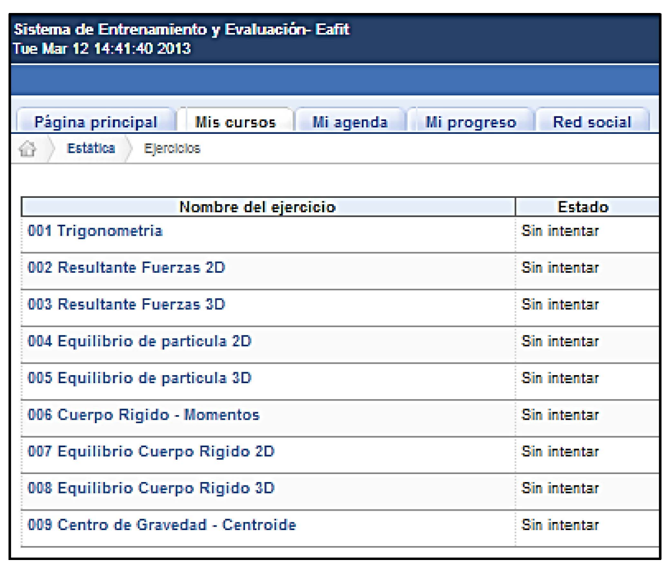

Fig. 4. Interface for students to select a test.

Processes of automatic generation of tasks was designed for being used in the web and implemented in Java language [29]. The generator algorithm produces various versions of the task by modifying the variables previously defined using random values within particular ranges. The variation includes also graphs and text that accompany the tasks generated.

According to the question format (i.e., multiple choice, matching, true or false and open written response) the correct solution must be programmed. Incorrect options are also programmed based on students' most common errors. This helps identify student misconceptions (see Figure 5). Data of students' wrong responses is not used, but all of this information is stored in the results database.

The program output is a file in one of the following formats: txt, xls, pdf and XML [30]. The XML formats like XmlMoodle [25] and QTI2 [26] are powerful and useful to transfer question and complete tests between different platforms. QTI2 is supported by many E-learning platforms.

Some instructional systems include: simulation tools (myphysicslab [31]), online courses platforms (WileyPlus [32], Connect Mcgraw Hill [33], and Courseconnect Pearson [34]). Most of these systems are commercial products which cannot be easily changed or adapted. Instead the approach presented here is flexible and affordable.

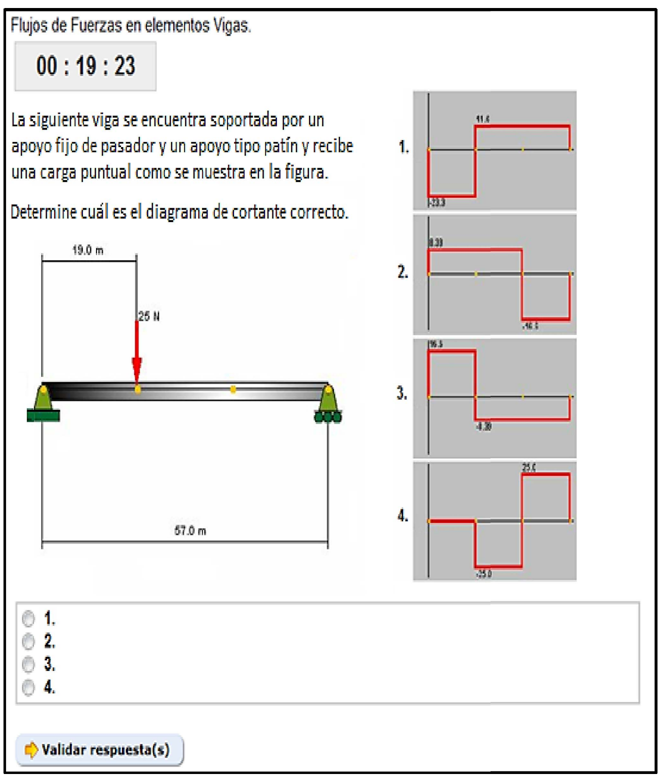

Fig.5. Example of a generated problem (response options correspond to the figures on the right).

V. Description of the Study

The subject of Statics and other engineering basic courses have high levels of student failure [1], with percentages close to 30%. The course is offered at the EAFIT University to about 200 students each semester in three different engineering programs. Success on the course objectives is determined by students' performance on various tests administered by the courses coordinators. Students pass the course when they achieve a success rate of 60% (a score of 3.0 on an absolute scale from 0 to 5.0).

In 2011, the Mechanical Engineering Department at EAFIT University took the initiative to change some aspects of the course through the implementation of a system for training and evaluation. The objectives were to provide a tool to improve the acquisition of knowledge and consequently improving the performance of students in the class of Statics. Further it stimulates the uptake of Information and Communication Technologies in the institution.

This system has been used in Statics courses during the 2 semesters of 2012, with the participation of 384 students from 12 different groups. The results of this experiment are compared with the results of other students from previous years who were evaluated without using the system for training and evaluation that uses the automatic task generation engine [12].

The system was introduced in 2012. It was used by students as a practice system. Student performance accounted for 20% of the final grade. On average each student solved 40 questions on each topic.

Data for this study includes result of tests of students from 2006 to 2012. The first 5 years (2006-2010) correspond to students who did not use the proposed evaluation system, 2011 students used a preliminary version of the system and 2012 includes data from students who used the system. The scores averages per year for all students are shown in Figure 6.

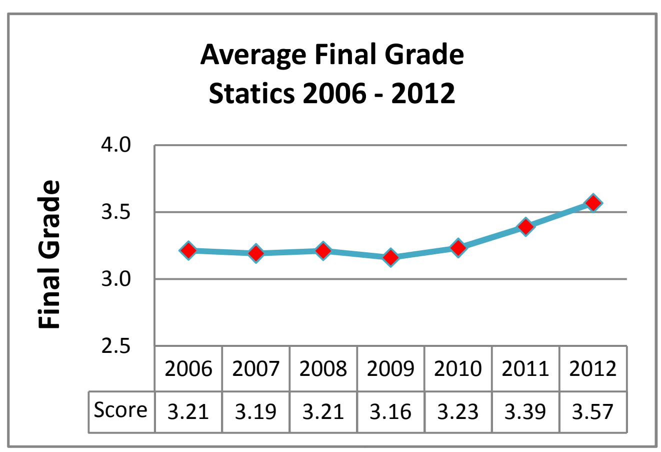

Fig. 6. Average Statics grade for 2006 to 2012.

The failure rate for a group IR in an academic period is calculated by the formula: IR = (RA / TA) x100 where (RA) is the number of students who did not get the minimum score and (TA) is the number of students formally enrolled in the course. The figure 7 shows the percentage by year of the students that failed the class in (2006-2012).

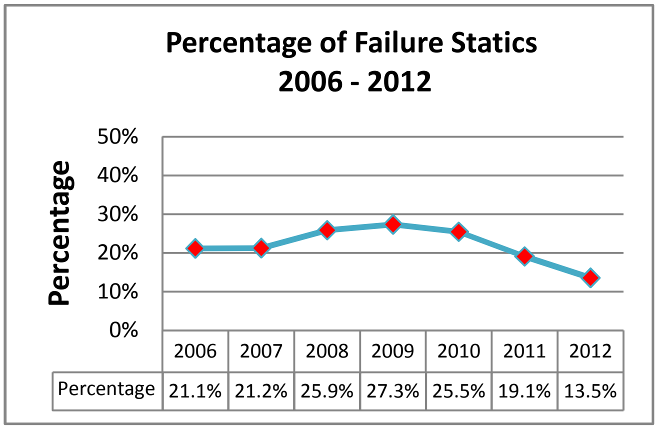

Fig. 7. Static fail rates for each year from 2006 to 2012.

Between 2006 and 2010 the students were evaluated with paper and pencil tests. During 2011 and 2012 students were evaluated with a combination of paper and pencil tests taken from the guide books, and computerized tests created by the automatic task generation system.

For the analysis two samples have been selected. The first sample (sample 1) includes the results of 1290 students, who were the total enrolled in the course between years 2006 and 2010, and the second (sample 2) includes 384 student, who were the total enrolled in the course in 2012.

2011 students were not included in the analysis of the results because that year the system was in a building phase and students used a preliminary version of the system. A comparison of the results was made to measure the changes in students' scores averages of the e-learning evaluation platform on the subject.

Finally a statistical analysis was performed and it includes tests to see if the data of the two samples follows a normal distribution, medians comparison, average analysis, and effect size test were made.

It is important to mention that the final course test is a pencil and paper test and its difficulty level has been kept the same throughout the years.

VI. Results

The figures 8 and 9 show the frequency histogram and the normal distribution fit for the sample 1 and sample 2.

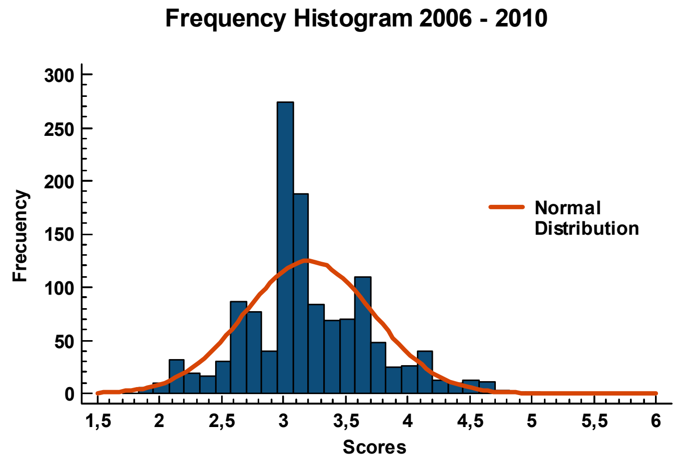

Fig. 8. Frecuency Histogram for sample 1.

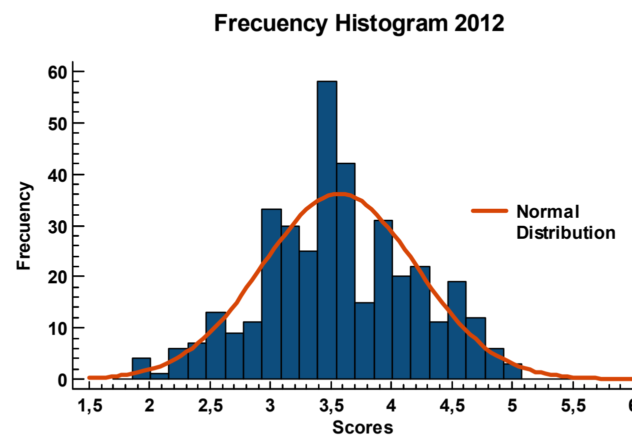

Fig. 9. Frecuency Histogram for sample 2

Table I shows the results of the Goodness of fit test (Kolmogorov–Smirnov) [35], which check the normality of samples.

TABLE I. RESULTS OF GOODNESS OF FIT TEST

	Sample 1	Sample 2
D max	0,107	0,063
D min	0,104	0,054
DN	0,107	0,063
Value-P	0,0	0,099

The P-value of sample 1 is less than 0.05, because of this the hypothesis that sample 1 data comes from a normal distribution should be rejected with 95% confidence. For sample 2 the P-value is greater than or equal to 0.05, the hypotheses cannot be rejected then sample 2 data comes from a normal distribution with 95% confidence.

Since the goodness of fit test for sample 1 did not fit a normal distribution, an average comparison between each sample cannot be done, then a comparison of medians test through Mann-Whitney (Wilcoxon) [36] was done. The results of this test are shown in Table II.

- Null hypothesis (1):

$$\text{Median sample } 1 = \text{Median sample } 2 \quad (1)$$

- Alternative hypothesis (2):

$$\text{Median sample } 1 \neq \text{Median sample } 2 \quad (2)$$

TABLE II. RESULTS OF MANN-WHITNEY (WILCOXON) TEST

Median Comparison	Sample 1	Sample 2
Median	3,1	3,5
Average Range	770,67	1066,62
W	331551	
P-value	0	

As the P-value is less than 0.05, then the Null hypothesis can be rejected with alpha = 0.05. There is a statistically significant difference between the medians with a confidence of 95.0%.

Finally to determine how significant the difference between the samples averages is, the effect size is calculated in (3).

$$d = \frac{\bar{x}_1 - \bar{x}_2}{s} \quad (3)$$

Where x1 and x2 are the averages of samples and "S" is the control standard deviation. The results of this test are shown in Table III.

TABLE III RESULTS OF COHEN EFFECT SIZE TEST

	Sample 1	Sample 2
Average	3.20	3.56
S	0.52	0.64
effect size	0.62	

It was found that the sample effect size is equal to 0.62, which is a moderate effect size.

After validate statically the reliability of data, the results of the differences between the averages scores and between the failure rates for two samples are shown in the Figures 10 and 11.

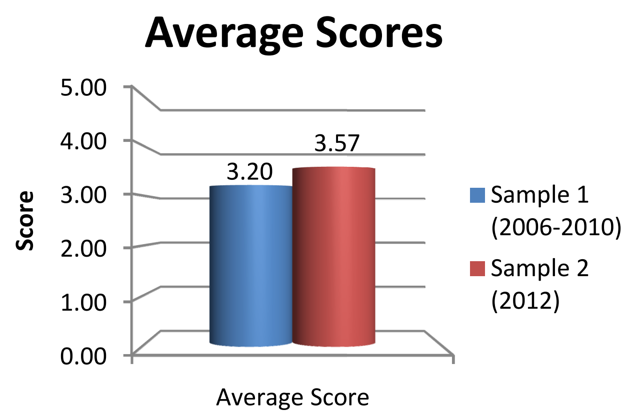

Fig. 10. Average scores for two samples.

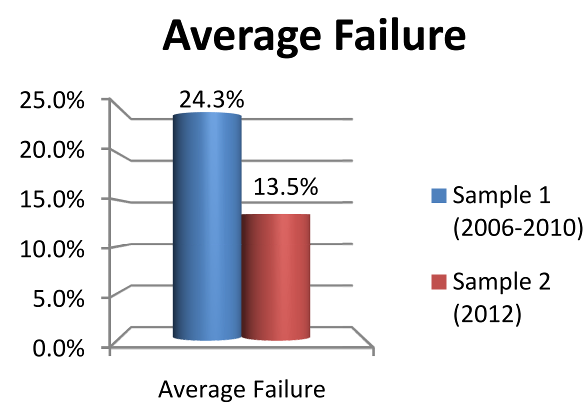

Fig. 11. Average Failure for two samples.

VII. CONCLUSIONS AND FUTURE WORK

The Statics grades for 2012 increased about 8% compared to those from 2006-2010. In addition, the percentage of failure has considerable decreased in 2011 and 2012 about 11% compared to those from 2006-2010. This is expected to have an influence in reducing dropout rates of engineering programs Mechanical, Civil and Production engineering. However, more information is needed to measure the impact of the system on dropout rates (e.g., other information on student progress, instructional changes in other classes, and teacher effects).

It should be noted that the subject of Statics is not the only subject that has high levels of failure. Also, other non-academic aspects influence desertion of academic programs.

Some students did not use the system for continuous assessment. More research needs to be done to find out why these students did not take full advantage of the system.

Part of the success of the system can be attributed to an increase in student motivation generated by the system.

Students appreciated the opportunity to use the system in other places outside the University. The LMS platform logs shows that a high percentage of the connections comes from outside the university

The development of the tool has generated interest from other academic departments and studies are in progress to adapt the system in other core subjects.

REFERENCES

[1] Ministry of Nacional Education Viceministerio de Educación Superior "Desercion Estudiantil en la Educación Superior Colombian monitoring methodology, diagnosis and prevention elements for Ministry of Education", (2009).

[2] D. Hestenes, M. Wells, G. Swackhamer "Force Concept Inventory" Published in: The Physics Teacher, Vol. 30, March 1992, 141-158

[3] P.S. Steif. "Initial Data from a Statics Concept Inventory", Proceedings of the ASEE (2004).

[4] T. Goldfinch, A. Carew, G Thomas. "Students Views on Engineering Mechanics Education and the Implications for Educators" Proceedings of the 2009 AaeE Conference, (2009).

[5] R. Karim, "Teaching and Learning of Statics and Mechanics of Solids: Some Problems and Solutions" Proceedings of the 2010 AaeE Conference, Sydney, (2010).

[6] J. Biggs, "Quality of university learning". Narcea, SA Edits. University collection. Second Edition, Madrid, España. Released Open University Press, Buckingham.pp. 29. (2006).

[7] J. Restrepo, "Automatic generator of tasks in support of the evaluation process, static subject," National Meeting ACOFI. (2012).

[8] Soutas-Little, W. Robert.et al; "Engineering Mechanics: Statics" Prentice Hall, pp. 289. (2009).

[9] P. Boresi, R. Schmidt "Engineering Mechanics: Statics General Engineering". Brooks/Cole, Pensilvania State University, pp. 553. (2011).

[10] F.P Beer, Jr. Johnston; "Estática y Mecánica de Materiales". McGraw-Hill, Inc. ER (2007).

[11] R. C. Hibbeler "Engineering Mechanics: Statics", 13/E ISBN-10: 0132915545 Prentice Hall , pp 672. (2012).

[12] A. Kozuli "Dynamic Assessment of EFL Text Comprehension" School Psychology International, Vol. 23 Issue 01, February, (2002)

[13] L. Vygotsky, "The Problem of Age". The Collected Works of L. S. Vygotsky, Volume 5, pp. 187-205. (1998).

[14] e-Assessment Association, (online):http://www.e-assessment.com/

[15] Oracle, "Java SE 7 Certification", (online):http://education.oracle.com/pls/

[16] Education Testing Service, "GRE", (Online):https://www.ets.org/gre/

[17] Education Testing Service, "TOEFL", (Online):https://www.ets.org/toefl/

[18] Coursera, (Online):https://www.coursera.org/

[19] Y. Kats, "Learning management system technologies and software solutions for online teaching: tools and applications". Information Science Reference, s.l. pp. 20. (2010).

[20] S. Graf, "Advanced Learning Technologies", ICALT 2005. Fifth IEEE International Conference on Women"s Postgraduate Coll. of Internet Technol., Vienna Univ. of Technology, Austria. pp. 163. July (2005).

[21] Moodle.org: open-source community-based tools for learning, (Online): http://.moodle.org.

[22] Dokeos - Open Source Eleaning, (Online): dokeos.com.

[23] Blackboard International - LAC, (Online): http://www.blackboard.com/International/LAC.aspx

[24] Chamilo, E-learning & Colaboration Software, (Online):http://www.chamilo.org/es.

[25] Moodle, "Moodle XML Format", (Online):http://docs.moodle.org/24/en/Moodle_XML_format.

[26] IMS GLOBAL Learning Consortium, "IMS Quetions & Test Interoperability QTI2 Specification", (Online):http://www.imsglobal.org/question/.

[27] Amazon Web Servises, "AWS Global Summit Series", (Online): http://aws.amazon.com/es/

[28] Calculated Question Type, Moodle.org: open-source community-based tools for learning, (Online): http://docs.moodle.org/22/en/Calculated_question_type.

[29] Oracle Technology Network for Java Developers, (Online):http://www.oracle.com/technetwork/java/index.html.

[30] W3C Ubiquitous Web Domain, "Extensible Markup Languaje (XML)", (Online):http://www.w3.org/XML/.

[31] Myphysicslab (Online): http://www.myphysicslab.com/

[32] WileyPlus online courses (Online): https://edugen.wiley.com/edugen/secure/index.uni

[33] Mcgraw Hill Connect (Online): http://connect.mcgraw-hill.com/connectweb/static_pages/index/index.html

[34] Pearson Courseconnect (Online): http://www.pearsonlearningsolutions.com/courseconnect/

[35] A. Justel, D. Peña, R. Zamar, "A multivariate Kolmogorov-Smirnov test of goodness of fit", Statistics & Probability Letters, 35(3), 251-259. (1997).

[36] Lehmann, L. Erich. "Nonparametrics: Statistical Methods Based on Ranks" Prentice-Hall Springer 1st ed. Revised edition 2006, XVI, 464 p. (1975).