



# TEEM '17

Technological Ecosystems for  
Enhancing Multiculturality

## PROCEEDINGS

Cádiz 18-20 OCTOBER 2017



Proceedings

TEEM'17

# **Fifth International Conference on Technological Ecosystems for Enhancing Multiculturality**

Cádiz, Spain

October 18th – 20th, 2017

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TEEM'17 is organized by the **S**oftware **P**rocess **I**mprovement and **F**ormal **M**ethods (SPI-FM), **E**valuation in **F**ormative Contexts (EVALfor) and **G**Roup in **I**nter**A**ction and e**L**earning (GRIAL) research groups with the support of the University of Cádiz.



**Fifth International Conference on Technological Ecosystems for Enhancing  
Multiculturality (TEEM'17)**

University of Cádiz  
Calle Ancha, 16  
11001 Cádiz, Spain

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2 Penn Plaza, Suite 701  
New York New York 10121-0701

ISBN: 978-1-4503-5386-1

# Design and assessment of the impact of an e-textbook in the engagement towards the learning of Discrete Mathematics

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## ABSTRACT

Mathematics is vital for the training of professionals from various branches. Current research shows that the number of students with lack of academic achievement in mathematics is significant. In the case of Discrete Mathematics, its learning increases its difficulty due to various motivational, attitudinal and ability variables. Hence, the need of promoting academic proposals that raises the levels of engagement of students towards the learning of the subject.

The present research project aims to assess the effects of an e-textbook on the engagement towards the learning of Discrete Mathematics in university students. A quasi-experimental quantitative methodology is used. It will begin in a first phase with the application of a questionnaire to measure the levels of engagement of students with the learning of Discrete Mathematics. Likewise, the levels of satisfaction of students and teachers with the study materials of Discrete Mathematics will be measured.

A second phase will propose the design of an e-textbook as educational material. The results of the research will show the impact of the e-textbook elaborated in the engagement towards the learning of Discrete Mathematics, by a questionnaire applied to students who used the developed material.

The expected results will widely allow the design of educational materials to enhance the engagement of other issues in different teaching scenarios, which will be useful to improve the academic performance of the students in those subjects where the results are not the desired ones and it affects, therefore, the university quality standards.

## CCS CONCEPTS

• **Applied computing** → **Computer-assisted instruction; Interactive learning environments**

## KEYWORDS

Learning motivation, textbooks, mathematics achievement, academic performance, educational technology

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TEEM 2017, October 18-20, 2017, Cádiz, Spain

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## ACM Reference format:

Alién García-Hernández and Teresa González-Ramírez. 2017. Design and assessment of the impact of an e-textbook in the engagement towards the learning of Discrete Mathematics. In *Proceedings of 5<sup>th</sup> International Conference Technological Ecosystems for Enhancing Multiculturality, Spain, October 2017 (TEEM'17)*, 7 pages.

DOI: 10.1145/3144826.3145443

## 1 CONTEXT AND MOTIVATION THAT DRIVES THE DISSERTATION RESEARCH

The Ministry of Higher Education of the Republic of Cuba is the governing body of university centers and careers in the country. In 2016 began a process of improvement of Higher Education, aimed to orient the training process closer to learning rather than teaching. All of this with the objective of raising student's commitment and prominence and to favor their cognitive independence and creativity through the widespread use of computer programs, interactive platforms, virtual laboratory practices, among others.

At the University of Informatics Sciences (UIS) in Havana, the degree of Engineering in Computer Science (ECS) is studied, whose object of profession is the process of computerization of society, being understood as such, the one related to its participation in the redesign of the processes of the organizations, according to the needs for its computerization.

Within the subjects that are taught, Discrete Mathematics (I and II) is studied during the first year. This subject develops a logical and algorithm thinking; an essential element of the specialty of Computer Science. The objectives of Discrete Mathematics are directed to the modeling and the simulation of structures and processes that take part in the computational solution of problems.

The academic performance of students in Discrete Mathematics (DM) subjects in the ECS is not the expected, during the last academic years the percentage of students who did not exceed the subject in their ordinary examination is not

insignificant. If we analyze the official data of the institution, in the last five academic years, we see that more than 35% of the students need at least another opportunity to approve the subjects.

From this information, we should ask the following question: Are these levels of academic performance related to students' motivation and commitment to learning, or simply to the assimilation of highly complex content? It is worth noting that the level of student's involvement with their learning is not the desired.

For this reason as a background of this research and with the intention of investigating possible causes of this phenomenon, in the master's thesis of this investigator we analyze the main limitations of the teaching-learning process of Discrete Mathematics in the UIS from 2009 to the present. Some of the difficulties detected were:

1. Insufficient use of Information and Communication Technologies (ICT) in the teaching-learning process of the subjects, which distances the student of Engineering in Computer Science from the object of its profession.
2. Low use of the study materials of the subject. These materials do not fully conform to the objectives and abilities of the subjects; they also do not take into account graphing, interactivity and descriptions of step-by-step procedures to facilitate student learning.

The difficulties expressed have influenced the student's commitment to the learning of Discrete Mathematics, and therefore, in the low levels of motivation and commitment for their academic performance.

Precisely several studies on student's motivation and commitment point to a relatively young concept in education: engagement, which is invited to be studied by experts in higher education [36]. It is good to note that in Cuba we did not identify published studies on this subject. Most foreign investigations focus on the confirmation of the incidence of the concept and the factors that influence its existence in the students [15, 16, 22, 29, 38].

The scientific community advocates designing study materials with high levels of technological interaction that will help students cope with acceptable levels of engagement in the teaching-learning process of highly complex subjects [22].

Among the most used and preferred study materials by students and teachers are textbooks [12]. It is considered that a textbook can be an outstanding help in the teaching-learning process, however, the accelerated development of technologies and the presence of subjects with a high scientific rigor, among other causes, require professional training very complex to give by the traditional text- book [12, 24, 32].

This justifies the need of designing interactive textbooks that guarantee a learning of Discrete Mathematics more adjusted to the complexity of this subject, where students require study environments in which graphing, visualization and interaction play a primary role [4, 25].

## 2 STATE-OF-THE-ART

We will do a tour of the scientific literature on the research problem. Firstly, will be tackled a synthesis on the state of the question in relation to the learning of mathematics, specifically Discrete Mathematics. Then a tour of the concept of academic performance and the concept engagement associated with educational contexts will be made, particularly its different definitions proposals, as well as how to enhance it with the use of technologies. Finally, we will look at the current state of the introduction of interactive textbooks in learning, emphasizing their benefits, the types of designs used and some experiences of it use.

### 2.1 Main line of research on the role of Discrete Mathematics in the training of computers professionals

Academic performance in the area of mathematics is not the expected in several educational contexts [27].

The field of application of mathematics is constantly expanding. With the emergence of computer science, it was essential to work with numerable sets; the need to compute became essential. Accordingly, graph theory, logic and combinatorial theory among other subjects led to the emergence of a new area of mathematics: Discrete Mathematics (DM). As they express [28] a DM course should focus on correctness, logic and algorithms. However, most students have difficulty in learning the contents of this essential part of math. For this reason, the development of academic proposals is encouraged to promote the learning of this subject.

The main lines of research identified about the Discrete Mathematics in the training of computer professionals are:

1. Educational psychology in the learning of mathematics [51, 56]: students' behavior is studied, their affective difficulties to face learning and motivation as a concept that leads to a level of engagement of the students with their studies.
2. The problem solving [5, 8, 46]: the cognitive, personality, and individual abilities of students to deal with problem solving are studied.
3. Technology in learning of Discrete Mathematics [8, 10, 43]: Problems associated with the use of technologies in learning are studied, as well as technical and pedagogical proposals that contribute to the student being able to learn to learn.

In relation to the first line previously exposed, professionals from the University of Costa Rica [54] show as a starting point of their research the lack of student's commitment to their learning of Discrete Mathematics (so learning through technological environments is proposed, bringing the students closer to their object of profession). It is important to note that several authors agree with this point of view [2, 47, 55].

In the psychological line, [14] conclude that various factors affect student learning, including: test anxiety, expectations of success, academic self-concept, and academic stress. Several researchers perceive in the learning of Discrete Mathematics the need to reinforce basic mathematical skills that allow solving problems autonomously [11, 45]. A study

conducted at the University of Pennsylvania [10] stated that students have difficulties in their methods of study and in the selection of study materials, which affects their learning process. As for the study materials are recurrent research that agree that this variable is vital in the learning of Discrete Mathematics [40].

The learning strategies are seen as a common difficulty in several students, hence the search for mechanisms and techno pedagogical variants that will contribute to a more effective learning of DM [28]. Research shows as an element of marked difficulty the little significance that the students give to the contents of the DM, which is why they promote academic proposals that promote broad inter- disciplinary relationships with other subjects [21, 34].

In this analysis of the object of study, it is desired to highlight the development of students' computational thinking, of particular importance if one takes into account the type of career in which DM is taught [21, 31, 32, 40].

## 2.2 Engagement like a contribution to academic performance in educational context

There is no common criterion to define the concept of academic performance. The different definitions of this term focus on the student, on the institution, on the educational system and can have a total, partial or absolute character. Current research defines it as a multidimensional construct in which multiple factors influence [3]. Academic performance, especially in mathematics, is a concept in which not only the student's abilities and motivation are considered, but also other attitudinal, social, cognitive, affective, economic and institutional variables [52].

From this approach, we identify two broad lines of research in studies on academic performance. A first line focuses the study of the concept from a psycho-pedagogical point of view, contributing a group of academic proposals to potentiate to its strengthening [50].

A second line focuses on the study of the causes that influence academic performance, determining the variables that predict their behavior [13, 39, 53]. In this second aspect, many researches analyze variables that, in determined contexts, predict academic performance.

Social factors such as parental education, province of origin and others as motivation towards the study were analyzed by [15], highlighting the use of statistical models. Similarly, motivational variables predict academic performance in the scientific proposal of [6], who also emphasize as a predictive factor the behavior of students.

Academic performance in mathematics is determined by different authors starting from a group of attitudinal, social, cognitive and motivational factors [37, 39, 41]. Other research has focused on determining the effect on academic performance of the hours that the student devotes to work as a complementary activity to the study [48].

Several researchers [3, 15] emphasize focus their studies on motivational variables. The results of these researches show a considerable improvement in performance when student's commitment and motivation levels increase. Hence, teaching

should focus on fostering a challenging and fun educational process, adjusted to the characteristics of each student with an emphasis on a techno- logical environment. The present factor among others determine that the intelligent use of ICT is seen by [18] as a predictive factor of engagement in studies.

The concept of engagement (involvement or commitment of the student with their learning) is related as a facilitator of the academic performance of the university students, with a greater motivation, a greater effort to solve their tasks and with less propensity to fail in the studies [44].

Achieving engagement in students is a complex task. Entrance to university is a critical moment in the student's life. The student faces unfamiliar life forms, where his own expectations and those of his family put pressure on him [23]. Almost no research conceptualizes engagement from a pedagogical perspective, from which, [9, 18] conclude that to generate engagement ICT should be used in universities, propitiating in the classrooms the following characteristics:

1. Interaction: it starts from the idea that people are social and interactive beings. In addition the era of the new technologies offers a wide variety of tools to foment the interaction like forums, chats, etc.
2. Exploration: the student of today must realize the need to be able to explore to learn how to respond to his difficulties by presenting this principle as an alternative to receive the guidelines set by another person.
3. Relevance: Another element to take into account when promoting engagement in students is the usefulness of learning and its application to real-life situations.
4. Multimedia: Education must pay attention to the techno- logical advances undergone by society, without creating a gap between school and reality. Connecting, in this way, these two spaces increase the chances of getting the involvement of the students.
5. Instruction: this category refers to the need for a change in the way of teaching and in the content to be transmitted, emphasizing in this change the constructivist approach as the most appropriate.

For this reason, a quality education that produces adequate levels of engagement, must be in line with the speeches, aspirations, intelligences, abilities and habits of the students and of the cultural and technological moment in which it develops. The technological environments should propitiate the learning of students, in such a way as to enable them to develop the totality of their capacities in a motivating and challenging way [18].

We would like to conclude this section by emphasizing the contributions of [22], who have determined that investigating engagement is vital to monitoring students' involvement in achieving their academic goals. Measuring students' commitment and academic performance will enable to build ICT tools to help them cope effectively with the teaching-learning process.

## 2.3 E-textbooks in learning

The textbook is a common tool for higher education, there are hundreds of textbooks written each year, yet almost nothing has been written about the educational principles for their design [17].

The published works, also occasionally, refer to some simple educational principles for designing textbooks, being the two fundamental principles [1]:

1. The didactic quality of the textbook according to the subject to be taught, enhancing the scientific skills and depth of content.
2. Simplify the language, in order to bring near complex content to students' learning in a dynamic and affordable way.

With the emergence of e-books, known as e-book, interactivity is the protagonist in the reading process. According to [7] the important consideration is how modern supports promote new ways of teaching before impossible. This element is substantial in university e-textbooks.

The e-textbook replaces the ideas of sequentially and causality with those of integrated and continuous activity. Instead of talking about products one could speak of processes in which the work is maintained in a permanent opening [26].

The e-textbook fits students by allowing them the ability to learn and read in both online and off-line environments. Their principal's functional characteristics are [57]:

1. The integration of digital media such as images, text, audio, videos, etc.
2. Provides a learning path more suited to the interests and abilities of each individual student.
3. Allows interaction between humans under their own learning environment.

The authors of this project agree with [26] when it states e-textbooks as learning objects available in web format to be used by teachers, students and parents, without time and space limitations, whose data can be updated quickly and accurately, with the characteristics of exchange, openness and dynamic generation.

The e-textbooks are use more and more in several countries; some- times complement textbooks in hard format, and often replace them completely. In the United States and Europe the number of institutions adopting open educational resources in textbooks has been increasing, even some schools have decided to adopt these features in their curricula [42].

The previous consideration has had a great impact on the teaching of mathematics, in the International Commission on Mathematics Teaching held at Oxford University the following question was asked [30]: How should new texts to interact effectively in the teaching of mathematics? Of course, studying the differences between textbooks and e-textbooks in terms of design, content, or their implications for the teaching-learning process of mathematics is a goal of the international scientific community [19]. It is worth noting that studies that address the design of e-textbooks [20, 26, 33, 35, 49] agree that the quality of learning increases, and thus academic performance, when students participate in more interactive environments.

### 3 PROBLEM STATEMENT

The purpose of this doctoral thesis is to design and evaluate an interactive textbook that allows students engagement in the

learning of Discrete Mathematics; improving their academic performance in this matter of essential importance in computer careers. In concrete form, the research problem is how to contribute to the engagement towards the learning of the Discrete Mathematics in the titulation of Engineering in Computer Science?

### 4 RESEARCH OBJECTIVES

The present research has as general objective: *to evaluate the effects of the design of an interactive textbook in the engagement towards the learning of Discrete Mathematics in the career of Engineering in Computer Science.*

To meet this goal we define the following specific objectives:

1. To know students and teachers satisfaction with the study materials of the subject Discrete Mathematics.
2. Describe the levels of engagement towards the learning of Discrete Mathematics presented by ECS students.
3. Identify the characteristics that a study material must possess to contribute to the engagement towards the learning of Discrete Mathematics in the ECS degree.
4. Design an interactive textbook of Discrete Mathematics based on the identified characteristics.
5. Evaluate the impact of the utilization of the interactive text- book, it relationship to academic performance, it overall satisfaction, and it contribution to student engagement.

### 5 METHODS

The present research responds to a quantitative quasi-experimental design based on a multistage approach.

In the initial phase, the research will focus on a descriptive study based on a quantitative cut-off methodology, in which we will use a survey-type design to gather information on teachers and students about the main constraints of study materials to contribute to the academic performance of students.

We will apply a questionnaire to the students previously surveyed. The questionnaire will seek to describe the levels of engagement towards the learning of Discrete Mathematics of the students of the Engineering in Computer Science's degree. In the second phase, we will use a quantitative methodology, based on an ad hoc questionnaire applied to students and teachers; accordingly we intend to determine the characteristics that the interactive textbook to be designed should have.

In the last phase, we will use a quantitative methodology to evaluate, from a questionnaire to students and teachers, the effectiveness of the e-textbook elaborated in terms of utilization, relation with academic performance and contribution to student engagement towards learning of Discrete Mathematics.

At the present moment in which this research is found, we want to emphasize that in the first phase we create a mathematical model of multiple linear regression, by the ordinary least squares method. With the model created, we try to predict the low academic performance in Discrete

Mathematics, in the Computer Science Engineering career, from independent variables.

The independent variables that complete the model are:

1. G: gender.
2. P: province.
3. MA\_T: math access test.
4. O\_T: option in which the student applied for the titulation.
5. SM\_MC: study materials' motivational capacity.
6. SM\_BL: contribution of study materials to better learning.
7. SM\_ACO: adequacy, of the study materials, to the contents and objectives of the subject.
8. SM\_AP: quality of study materials to contribute to academic performance.

At this stage of research aims to determine the influence of independent variables on the dependent variable: academic performance in Discrete Mathematics.

### 5.1 Sample of the study

The population of teachers is made up of the 24 professionals who teach the Discrete Mathematics subject at the University of Informatics Sciences, as the number is not high, we will perform the analyzes on all subjects of the population.

In the case of the students, all of them carry out their first year studies in the Introductory Faculty of Computer Science. We will analyze the student population in two academic courses:

1. Course 2016-2017 (907 subjects in the population) for phases 1 and 2.
2. Course 2017-2018 (800 subjects in the population) for phase 3.

We will carry out a random sampling by quotas taking into account the variables: teaching group, province, gender and academic performance in the subject and mathematical access note.

## 6 RESULTS TO DATE

This research completes one year of development. The main results are related to the first phase. We designed and applied a questionnaire to know the satisfaction of students and teachers with the study materials of the Discrete Mathematics subject.

Another questionnaire, designed by professors of the University of Seville, was redesigned and applied with the aim of describing the levels of engagement towards the learning of Discrete Mathematics presented by the students of the Engineering in Computer Science.

The data collected in the previous questionnaires served to complete the multiple linear regression model. In [Table 1](#) we can see that the general indicators of the model determined that the set of factors selected contributes significantly to explain the probability of having a low academic performance, which is reflected in the important percentage of correct prediction reached (in the order of 86 %).

**Table 1: Independent variable: academic performance. Logistic regression model**

Independent variables	B	Sig.	Exp(B)
G	0.160	0,627	1,173
P	0.738	0,040	2,091
MA_T	-1.085	0,000	0,338
O_T	0.221	0,306	1,247
SM_MC	-0.924	0,007	0,257
SM_BL	-0.267	0,045	0,758
SM_ACO	-0.038	0,202	0,963
SM_AP	-0.385	0,480	0,809

Model prediction: 85,6%

The variable that refers to *gender* has an odds ratio (Exp (B)) very close to the unit (1,173), so that it practically has no influence on the probability of achieving (or not) a low academic performance. In addition to that, its level of significance does not meet the established parameters.

The variable that refers to the *province* has a level of significance lower than 0.05 (0.04) so we can ensure that it influences the dependent variable. Its estimate of odds ratio indicates that students who are from the capital of the country have 2,091 fewer possibilities to fail than those students who come from the rest of the country.

The *option variable in which the titulation was applied* has a significance level higher than 0.05, which means that it has no significant influence on academic achievement. The variable that refers to the previous results of the *mathematics entrance test*, is indicating that, in a student with high entrance grades, the probability of failing Discrete Mathematics is reduced by 66%.

Variables associated with *study materials* show variety of results. Students who perceive a high motivational ability with study materials are four times more likely to perform well academically. Variables associated with learning ability and overall quality of materials indicate that those students who value these variables with the highest level have approximately 20% less probability of achieving low academic performance compared to the rest of their peers. As for the adequacy of the study materials to the contents and objectives of the subject, this variable has a significance level higher than 0.05; so it has no significant influence on academic performance.

## 7 DISSERTATION STATUS

The results obtained have allowed us to diagnose the current situation regarding the satisfaction of students and teachers with the study materials of Discrete Mathematics, determining,



from statistical regression analysis, that students who have low satisfaction with study materials of the subject have a higher probability of suspending the subject.

In this sense, students who perceive a high capacity of motivation with the materials of study are four times more likely to have a good academic performance. Variables associated with learning ability and overall quality of materials, indicate that those students who value them with the highest level, have approximately 20% less probability of achieving low academic performance compared to the rest of their peers.

These results bring the need to design educational materials that contribute, from higher levels of satisfaction, to better results in the academic performance of students.

We are currently analyzing an applied survey to identify the levels of engagement, which the students present, towards the learning of Discrete Mathematics. This processing will allow us, based on statistical analysis of multilevel, to determine the relationship existing with the academic performance of students and satisfaction with their study materials.

The results discussed above will allow us in the next phase to design and evaluate an e-textbook from identifying the characteristics that both students and teachers consider should have a study material of this type to generate engagement in the students.

Finally, we will be use the e-textbook in a selected sample, with the aim of evaluating its impact on the engagement towards the learning of Discrete Mathematics in the Computer Science Engineering career.

## 8 CURRENT AND EXPECTED CONTRIBUTIONS

This research has as a first result the concretion of a questionnaire to determine the satisfaction of students and teachers are the study materials.

Among the current contributions, it is worth highlighting the creation of a statistical model of prediction of academic performance, based on social and motivational variables, which contributes to institutional decision-making with the objective of increasing the chances of students' success in learning of Discrete Mathematics and in other subjects.

The results obtained reinforce the research problem raised. We expect that in the following phases to provide as results, first, the design of an e-textbook of Discrete Mathematics.

After evaluating the effects of the e-textbook designed in the engagement towards learning, we will be able to obtain as a fundamental contribution of this research the design of an e-textbook with the aim of being able to generalize its conception to other contexts and subjects.

## ACKNOWLEDGMENTS

We are grateful to the Ibero-American Postgraduate University Association (AUIP), the University of Seville and the University of Informatics Sciences for their material and financial contributions to the development of this research.

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