International Journal of Engineering Education Vol. 34, No. 2(A), pp. 388–399, 2018
Printed in Great Britain
0949-149X/91 $3.00+0.00

Using Video Games to Promote Engineering Careers*

CARLOS VAZ DE CARVALHO
GILT—Graphics, Interaction and Learning Technologies, Instituto Superior de Engenharia do Porto, Rua Dr. António Bernardino de Almeida, 431, 4200-072, Porto, Portugal. E-mail: cmc@isep.ipp.pt

MANUEL CAEIRO-RODRÍGUEZ and MARTÍN LLAMAS NISTAL
GIST- Grupo de Ingeniería de Sistemas Telemáticos, Universidade de Vigo, Campus Universitario, s/n, 36310 Vigo, Pontevedra, Spain. E-mail: mcaeiro@det.uvigo.es, martin@gist.uvigo.es

MELANI HROMIN and ANDREA BIANCHI
To Get Pro Consortium, Via Previtali 18, Bergamo, Italy. E-mail: {melani.hromin, andrea.bianchi}@togetpro.it

OLIVIER HEIDMANN and HARIKLIA TSALAPATAS
Institute for Research and Technology, University of Thessaly, Argonafton & Filellinon, 38221 Volos, Greece.
E-mail: olivier.heidmann@gmail.com, htsalapa@uth.gr

ALPER METIN
Hayme Ana Mesleki ve Teknik Anadolu Lisesi, Ertuğrul Gazi Mahallesi. Sonbahar Sokak, 06930-Sincan, Turkey.
E-mail: alpermetin-@hotmail.com

Worldwide studies show that science and technology careers are not very attractive to younger students. The declining student interest in engineering careers is problematic due to the existing shortage of engineering professionals and this situation needs to be quickly improved. Initiatives setup to tackle this situation have been too focused on formal education and results were not impressive. New tools and strategies are required to address this issue in such a way that matches the interests of the youngsters. ECity is a European initiative that motivates students to follow an engineering career by giving them a basic understanding of engineering problems and tasks through a city-simulator video-game. Implementation results show that there is a correlation between the enjoyment of the game and the understanding and willingness to follow the engineering path. Results also show that the game had a higher impact in younger, basic-education students than in older, secondary education students. Therefore, this kind of initiatives should take place at an early age-level.

Keywords: engineering; engineering careers; serious games; simulation; STEM; video games

1. Introduction

Being one of the first choices of students' careers in the 90s, engineering has since lost its place in the minds and dreams of young people. Following the results of the PISA (Programme for International Student Assessment) study in 2012, the OECD reported that the percentage of 15 year olds that were then planning a career in engineering and computing was only 12.5% in Greece, 14.9% in Portugal, 14.4% in Spain, 7.2% in the UK and 9.4% in the US. The average in the OECD countries was only 11.3%. The OECD also mentioned that, although the absolute number of science and technology students had increased over a period of 15 years, the proportion had declined when compared to all higher education students [1].

This is not a specific engineering issue, but it relates to the domains usually grouped under the STEM (Science, Technology, Engineering and Mathematics) acronym. There are different social, cultural, economic and educational reasons that try to explain why these studies and careers are unattractive for young people [2]. Social reasons relate to the immediate student's environment (family and friends) but also to biased societal gender perceptions. Cultural reasons relate to the positive or negative way the surrounding society views science and technology and the impact that it can have on the overall student's perception of STEM careers. In the same sense, economical reasons can dictate either positive or negative perceptions as, for instance, unemployment in STEM domains is minimal but wages are relatively low compared with managerial positions. The way in which STEM subjects are taught also has been shown to have a large influence on students' attitudes towards science and on their motivation to study and, consequently, their achievement. In fact, Yelamarthi et al mention that the majority of teachers at these levels lack engineering understanding in spite of the fact that "early exposure to engineering research and design experience is crucial for students" [3].

Active learning methodologies have been shown to contribute to a higher student motivation towards STEM careers. Chen and Soldner reported that the performance of students in STEM courses emerged as a significant factor that affects attraction rates [4]. The PISA report that focuses on the

* Accepted 21 November 2017.

performance of students at age 15 confirmed a correlation between the general student performance in earlier STEM courses and their general intention to follow a STEM career [1]. Similar observations are documented at even younger ages by the TIMSS (Trends in International Mathematics and Science Study) assessment by the National Center for Educational Statistics of the US, which focuses on the performance of students on the same subjects at grades 4 and 8 [5].

Another important factor is the lack of knowledge of younger students about what engineering really is. Villanueva and Nadelson indicate that a critical part of a student's career development is their acquisition of a professional identity [6]. However, Kutnick, Chan and Lee noticed that access to an early understanding of engineering was provided mostly through home contacts and not by the school [7]. Cerinsek, Hribar, Glodez and Dolinsek found that families, teachers and even popular television programs had a much more considerable influence in promoting interest in STEM careers than schools. In fact, there was a limited exposure to advanced STEM subjects till secondary education (age 15+), even though most students chose their career before they turned 14 [8].

As a consequence, the growing shortage of engineering professionals is becoming a global threat to industrial growth. The EngineeringUK organization identified a shortfall of 44 000 engineers in the United Kingdom alone and called for actions to train and retain engineers [9]. Concurrently, 65% of the experts interviewed for the IEEE Spectrum Forecasters STEM Survey reported that there were too few STEM professionals in the world [10]. According to the Engineering Employers' Federation (EEF), four out of five manufacturers experience recruitment difficulties in hiring engineers. This is particularly relevant because, according to the EEF, "[. . .] access to productive and skilled employees is a key requirement for manufacturers of high-value goods and services" [11]. But also, because, like Lantada et al state, "the path to the future requires the best possible trained engineers for further developing and mentoring the technological advances that are reshaping the present" [12].

This means that the enrolment in Engineering and STEM fields in Higher Education must increase and students must be attracted towards these areas [13]. The inadequate attraction and retention of talent in engineering justifies a reinforced and innovative intervention to promote a higher engagement of learners in these fields. A career inspiration approach before university studies is necessary to "develop public and policy awareness and understanding of engineering, affirming the role of engineering as a driver of innovation, social and economic development" and to "transform engineering education, curricula and teaching to emphasize relevance and a problem solving approach to engineering" [9, 14]. New tools are required to motivate and engage a new generation of technologically-savvy youngsters [15]. The use of videogames to promote engagement and motivation is a good approach to enhance the image of engineering, according to [16–18].

The eCity project is a European initiative addressing the goal of motivating young students for an engineering career, by showing its connection to real-world issues [19]. This is done through a city-simulation game in which learners are exposed to non-trivial problems that challenge them to think as engineers, applying and combining skills from a wide range of STEM subjects to design solutions that positively affect quality of life and safety. Examples of these challenges include designing a city's power delivery network, protecting a city from earthquakes, setting up a mobile communications network, protecting a city from floods, etc. This paper introduces the eCity game and the results from an evaluation study involving more than 850 students in 5 European countries: Portugal, Spain, Italy, Greece and Turkey. The main goal of this study was precisely to assess the effectiveness of the game in promoting engineering careers.

The rest of the paper is organized as follows: the next section introduces the eCity game. Section 3 shows the research methodology and section 4 presents and discusses the collected results. The paper finishes with concluding remarks.

2. Presentation

Currently, policy approaches related to encouraging STEM studies and careers in Europe focus on: (a) curricular and teaching methods, (b) teacher professional development and (c) guiding young people to STEM [2]. This approach is replicated in most Western and Asian countries. Therefore, the majority of policies and initiatives being undertaken to encourage STEM take-up address educational factors and not the social and cultural ones. Furthermore, most of these initiatives only focus on the formal educational process and its stakeholders. At most, there have been some initiatives, like STEM fairs, trying to raise the awareness of students to STEM and by linking it to other stakeholders like industries and companies. One of these initiatives with a wider scope is the inGenious platform, a partnership between industry players, national Ministries of Education and other key education stakeholders, to promote interest in STEM studies and careers [20]. Nevertheless, it is not totally surprising that, despite the various policies, initiatives, programmes and projects developed in order to encourage STEM studies very little progress was achieved even if a few positive results appeared in the past few years [2].

New methodologies and tools are required to motivate and engage this generation. Tools like video-games, simulations, virtual and augmented reality, online social environments providing ubiquitous access to information and communication which are closer to the interests and habits of the new generation of students. These emerging technologies need to be taken in consideration by policymakers, researchers, developers, and educators when planning the future of STEM education [21]. Education can no longer be restricted to the formal environments but must be extended and include real-life contexts.

Video-games, in particular, have been extensively (and successfully) used to teach STEM concepts and to a certain extent to raise the awareness about STEM fields. A nice example is the game Reach for the Sun, in which players have to balance the right amount of starch, water and nutrients to enable their plant to grow and reproduce, therefore acquiring some notions about biology [22]. Another well-known example is SimCityEDU: Pollution Challenge! where students address environmental issues in a virtual city while maintaining employment levels and citizen happiness [23]. The actual game design and game development process can also be used to foster STEM awareness and interest. Specific platforms are available to allow students to design and develop their own games, like MIT's Scratch [24], Gamestar's Mechanic [25] and Microsoft's Kodu [26].

For the specific field of engineering, it is important to distinguish between video-games that support learning and/or teaching which are usually meant to be used by students already enrolled in higher education engineering courses, and the video-games specifically designed to promote engineering careers in younger students. There are a few good examples and substantive research for the first group, but they are out of the scope of this article. For the second group, the availability of resources is much scarcer, and games are normally quite simple (mostly puzzle-like) and very specific in scope and focus. Examples can be found at the engineering.com website that provides a series of games meant to promote the interest and motivation for the field [27]. IBM, IEEE and the Teacherstryscience association teamed up to create the tryengineering.org site also with several resources and games to motivate students to follow an engineering career [28]. SpaceBOX created the engineering-games.net site with several engineering related games [29]. There are also several city development games which mostly focus on energy and environmental issues like EnerCities [30], ElectroCity [31], EcoVille [32], CityOne [33] and envKids [34]. Specific research in the use of video-games to motivate students to follow engineering careers is even scarcer: one of the few examples is reported by Valdez, Ferreira, Martins and Barbosa that used, successfully, a 3D virtual reality game to promote electrical engineering education [35].

2.1 eCity

eCity is a video-game specially designed to promote engineering careers in younger students. In the game the player assumes the role of city Mayor and becomes responsible for developing his/her city by overcoming challenges related to different areas of engineering: geological engineering, electrical engineering, environmental engineering, civil engineering, etc. The player is asked to build power plants (eventually solar farms and wind farms) to produce enough energy for the city (Fig.1); to distribute the produced energy; to protect the environment; to choose the right places to build and the right type of construction to ensure safe buildings; to ensure signal coverage for mobile phones; to plan transportation between cities and so on. When the player carries out the engineering tasks correctly, the population of the virtual city increases. On the contrary, if the students make mistakes like placing houses on earthquake fault lines, it leads to a decrease in the number of inhabitants.

The eCity game can be played in two different play modes: sandbox and scenarios. The sandbox mode is closer to an entertainment-oriented approach and the major goal is to create a city and make it grow as much as possible starting from zero inhabitants. This mode is also used to understand the logic of the simulation engine and the main features of the game. The scenario mode was conceived following the principles of Goal Oriented Action Planning (GOAP) that allows planning a sequence of actions to satisfy a particular goal. Each scenario involves a certain objective that has to be attained starting from a specific city configuration, with residences, factories, power lines, roads, communications, pollution, etc. The particular sequence of actions to solve the scenario depends not only on the goal, but also on the current state of the environment and the player ability and playing style. This means that, if the same scenario is given to different players, they can reach the end goal through a completely different sequence of actions, which makes the game more interactive, dynamic and realistic.

The idea of the scenarios also relates to the

Fig. 1. Screenshot of the eCity game.

concept of creating interdisciplinary experiences that try solving "grand challenges", issues that are not yet solved at the local community, national, or global levels. These challenges are highly motivational for these students [36]. Initially 8 scenarios (or engineering challenges) were created:

- Energy Distribution: The goal is to understand the basics of energy production and distribution. All the city buildings and dependencies must be correctly powered in an effective way. The game has distinct power and distribution plants, involving high, medium and low voltages. Players must ensure that there will be no breaks of distribution through redundant connections.
- Renewable Energies: The goal is to be familiar with renewable energy sources. Students are required to design the energy supply of a city entirely based on renewable energies. They are provided with a scenario with a city already with a few thousand inhabitants and existing coal and oil power production centrals that must be replaced in five years by wind and solar farms. Students must choose the best locations for the wind and solar farms to ensure the most cost-effective solution.
- Mobile Connection: The goal is to understand how a mobile phone network works. Students are provided with a city scenario and are required to deploy the different elements that make a mobile network, respecting the coverage area for each antenna, taking into account the coverage ranges and frequency.
- Internet Services Provider: The goal is to understand the basics of data distribution networks and how a computer communication network works. Students are required to deploy the network using some of the available elements, trying to provide a certain quality of service while maintaining a low cost.
- Public Transportation: The goal is to analyze and design an optimal public transportation network to a city and a set of nearby smaller villages. The basic interaction to solve this problem is placing bus stops along the roads. Although there is more than one correct solution, a compromise must be achieved between maintenance costs and transportation network quality.
- Earthquake Protection: The goal is to know about different types of soil and building structures, to develop consciousness about earthquake protection. Students are provided with a map including three different soil types. Land has different prices, so the student will choose the land, type of building and floors. Choosing the correct soil type will not be enough to build strong buildings because they will have to select the construction type and number of floors correctly, but at the same time give housing to as many people as possible.
- Flood Protection: The main objective of this scenario is that students understand the basic actions to prevent and control a flood. Students need to redesign a city layout in order to prevent new floods from destroying citizens' houses or at least to minimize the resulting damage.
- Pollution: The goal is to manage and reduce pollution and waste. The scenario shows a city with a huge pollution issue. Players must identify the causes of the pollution and find strategies to minimize that problem within the given budget ensuring that the city continues to grow.

Each eCity scenario is a challenge to be solved by the player through a set of common steps:

1. Players use the sandbox mode to get familiar with the game logic and interface. They can freely explore the game building a new city from scratch;
2. Players open a scenario and read the problem definition or formulation;
3. With support or alone, the players generate informally a knowledge inventory, that is, the list of the information they need to solve the problem. That information can be embedded in the game itself or can be accessed through the internet;
4. The player or team of players generate possible solutions and select the one that seems more efficient;
5. The players then proceed to implement their solution and verify if it leads to the desired results;
6. If done in a school environment, players can share the solutions and results and debate the different options.

3. Research methodology

The main goal of the research study was to assess the effectiveness of the eCity game as a tool to motivate students to follow engineering careers. The main concept behind this study was the idea that using a game to support solving engineering problems can lead to a better understanding of what engineering is therefore motivating basic and secondary education students to follow STEM and engineering careers. As such the main research question and main hypothesis were defined as:

H1: Students that enjoy playing the eCity game will be more aware and willing to follow an engineering career.

Naturally, to fully assess if a single strategy or tool does affect the willingness of a student to follow an engineering career is extremely difficult (if not impossible) as career selection is a decision taken as a result of the combination of many small unrelated (and many time unconscious) factors. It would in fact be necessary to isolate all other social, cultural, educational and economic factors throughout the whole period from the moment that the tool or strategy is applied to the moment that the student effectively chooses an academic path (and eventually making also sure he follows it until his/her professional placement) to measure the effective impact of such tool or strategy. Therefore, the goal of the study is rather to assess the correlation between enjoying playing the game and the reported willingness to follow an engineering career. If positive, it will justify setting up holistic and ubiquitous strategies where engineering oriented games have a more relevant role.

Complementarily the research study also wanted to assess if the age (namely between early and middle stage adolescents) and gender variables had any influence on the results. Additionally, because the study was setup in different locations, it was relevant to assess if the local cultural and social aspects had impact on the achieved results. Three secondary hypotheses were established:

H1.1: The impact of playing the eCity game in the understanding and willingness of following an engineering career is independent of the players' age.

H1.2: The impact of playing the eCity game in the understanding and willingness of following an engineering career is independent of the players' gender.

H1.3: The impact of playing the eCity game in the understanding and willingness of following an engineering career is independent of the players' location.

The research study followed a case-study methodology using a mostly quantitative approach combined with a qualitative approach to triangulate data from different sources and therefore reinforcing conclusions. One questionnaire was used as quantitative data collection tool for gathering large quantities of data, thereby providing the possibility of applying statistical techniques to recognize overall patterns and crossing characteristics across groups. The qualitative data collection tools (interviews and focus groups) were used to gather descriptive information and opinions to color the quantitative data.

This research methodology was preferred considering the possible time scope and goals of the study. Organizing the study using pre and post-game data collection might implicitly guide the students to "work" towards the goal of the study, therefore biasing the results. Therefore, the study was rather focused on the assessment of the correlation of playing and enjoying a game where real engineering problems require the players' attention and his/her focus towards engineering. This focus was defined as being composed by the following factors:

1. Awareness: being aware of real-life engineering problems and applications and the tasks and responsibilities of the engineers
2. Willingness: understand of the required individual and social competences and skills and being interested in developing those skills by following an academic path related to STEM

To measure these factors, the questions asked were as follows:

1. Awareness
   – The content is real life representative.
   – Playing the game, I became aware of some interesting engineering information.
2. Willingness
   – The game helped me to learn how to define problems and find solutions in a systematic manner.
   – After playing I am more motivated to learn similar subjects.
   – After playing I am more interested into following a technical academic path like engineering.

The factors conditioning the enjoyment of the player in the use (and reuse) the game were gameplay and usability. A full study on gameplay and usability was not intended as that was the focus of a different research process which led to strong conclusions on the successful entertainment aspect of the game for this audience. In this case, the approach to this variable related to its sole purpose of assessing the correlation nexus mentioned before so the included questions were:

1. Gameplay
   – The game is fun to play.
   – The game is challenging.
   – The game playtime is neither too long nor too short.
2. Usability
   – Controls of the game are easy to use.
   – The design of the interface is good.

The main user category taken in consideration were students in late basic education and students in secondary/vocational schools. Their teachers were also involved in the qualitative research process through interviews and participation in the focus groups. In total there were 885 students (871 valid answers) and 148 teachers involved. The testing sessions were conducted at the following locations: Thessaly, Greece; Bergamo, Italy; Porto and Braga, Portugal; Vigo and Valencia, Spain; and, Ankara, Turkey. According to the study objectives, it was decided to create the following groups:

- Two age groups were considered: basic education and secondary education students (roughly the first group from 11 to 14 years-old and the second one from 15 to 19 years-old). This division also follows a common identification of the first stage of adolescence and the middle/late stages. The early adolescent begins to demonstrate use of formal logical operations and to form and verbalize his or her own thoughts and views. The focus of middle adolescence expands to a deeper and abstract thinking, and to consider future goals and to make his or her own plans which in a late adolescent stage include career decisions [37]. Therefore, this separation allowed finding out if there were differences between these two groups.
- Gender groups, for the importance of social gender bias in most involved countries.
- Geographical groups, with the two Spanish sites were considered independently as there are clear cultural differences between the two location cities, Vigo in the North and Valencia in the South of Spain.

In Table 1 it is possible to see the number of students per group (only students with valid answers are included).

The number of participants per site is relatively balanced. Upper values (Valencia) or lower values (Greece) are not so extreme that might cause any interpretation problems. The same also applies to the gender distribution (there are more male students) and age distribution (more secondary education students). In the cases where this might have led to statistical significant effects, it was accounted for.

Concerning the qualitative research part, a set of interviews and focus groups were organized as a complement to the questionnaires. These activities included samples of the involved students and their teachers. In total, 12 of these activities were implemented, gathering 27 students and 148 teachers.

Implementation sessions lasted about two and

Table 1. Participants per site and per characteristics

	Male		**Female**		
Country	**11–14**	**15–19**	**11–14**	**15–19**	**Total**
Turkey		85		69	154
Italy	13	100		26	139
Portugal	42	73	18	17	150
Spain (Vigo)	9	38	13	45	105
Spain (Valencia)	28	90	29	81	228
Greece	31	22	27	15	95
	123	408	87	253	
Total	531		340		871

half hours on average, giving the students enough time to test approximately 2 scenarios. The methodology included the following steps:

- Explanation of the game context.
- Division of students in work groups (2-persons).
- Testing of the eCity platform using the *sandbox* mode.
- Scenario playing (students were monitored by their teachers).
- Filling evaluation questionnaires.
- Focus group session (5–10 randomly selected students, teachers and a moderator).

Each scenario was tested at least in three countries. The scenario with the least participants was the "Bus network" with just 135 and the larger number of participants was involved in the "Renewable Energies" scenarios with 509.

4. Results and discussion

The results of this study combine the descriptive analysis resulting from the most immediate measures of the quantitative data, the statistical analysis that leads to assessing the validity of the hypothesis and a set of quantitative comments that provide some depth to the previous numbers.

4.1 Descriptive data

In relation to the questionnaire, a 5-level Likert scale was used for each individual question, with score ranging from 1—Fully disagree to 5—Fully agree. Face validity of the questionnaire was established through consultation with other teachers and experts on the subject. The questionnaire was also pilot tested with a small group of students (not involved later in the data collection stage of the validation process) to identify weak and irrelevant questions. Following data collection, responses were entered into a spreadsheet. Data was then cleaned, and spurious errors identified which lead to removing several collected answers to obtain a total of 871 valid answers.

Table 2 shows the global statistical data concerning the full set of results. The questions related to factor 1 (Awareness) are more positively scored and the questions oriented to factor 2 (Willingness) were less positively scored. Nevertheless, the overall result from the set of questions indicates that the variable is positive.

Concerning internal consistency, the Cronbach α obtained was 0,77 which is very good for statistical purposes. For all the questions, the Shapiro-Wilks ($\alpha = 0.05$) test indicates that the distribution of answers approximates the normal function, so it is possible to combine the answers results to get the variable result.

Table 4 presents the average scores taking in consideration the different groups. Although still on the descriptive analysis side, these results already give some insight towards the analysis of the hypothesis.

We can find that males were much more motivated towards engineering career orientation than females which, unfortunately, is according to the common stereotypes. The exception to this conclusion was Portugal where female students preferred the game and Greece where results were balanced.

It is also clear that the impact of the game is higher on younger students than in the older ones which is clearly a positive aspect because at that moment students are still deciding their future. Finally, there is clearly one country were students were less positively impacted by the game, Spain (in both sites). However, this might have been strongly influenced by some less adequate equipment that was available in some basic education classrooms which hindered the testing.

Table 2. Frequency scores of the motivation questions

Question	**1**	**2**	**3**	**4**	**5**	$\bar{n}$	**Med**	σ
1. The content is real life representative	8.7%	12.5%	22.3%	31.7%	24.8%	3.51	4	1.23
2. Playing the game I became aware of interesting engineering information	4.4%	7.7%	18.4%	33.6%	35.9%	3.89	4	1.11
3. The game helped me to learn how to define problems and find solutions	7.3%	10.8%	27.2%	32.0%	22.6%	3.52	4	1.17
4. After playing I am more motivated to learn similar subjects	15%	14.7%	25.8%	26.4%	18.0%	3.18	3	1.31
5. After playing I am more interested in following a technical path like engineering	19.3%	16.3%	23.7%	22.2%	18.6%	3.05	3	1.38
Full set of questions	11.6%	14.1%	25.9%	32.1%	16.3%	3.43	4	

Table 3. Shapiro-Wilks test results for the questions

	Q1	**Q2**	**Q3**	**Q4**	**Q5**
W	0.954832	0.885415	0.92523104	0.819613	0.966487
p-value	0.7716174	0.334573	0.56423041	0.115968	0.852263

Table 4. Average scores of the motivation questions per group

	Male		Female		
Country	**11–14**	**15–19**	**11–14**	**15–19**	**Total**
Turkey		3.86		3.65	3.77
Italy	3.92	3.41		2.86	3.36
Portugal	3.70	3.59	3.92	3.73	3.68
Spain (Vigo)	2.76	3.29	2.46	2.72	2.96
Spain (Valencia)	3.66	3.20	3.10	2.99	3.18
Greece	3.93	3.42	3.87	3.37	3.71
	3.76	3.47	3.41	3.21	
Total	352		3.27		3.43

4.2 Discussion

In relation to *H1: Students that enjoy playing the eCity game will be aware and willing to follow an engineering career,* the gameplay and usability factors were used to assess the variable entertainment and its correlation to the actual perceived motivation to follow an engineering career. The overall results were quite positive ($\bar{x}$ = 3.64; Med = 4) indicating that students liked to play the game. The value for Pearsons' correlation, ρ, was 0.647 which indicates a strong positive correlation, in this context. A least-squares regression process was also used to assess the correlation between the two variables. The results obtained are shown in Table 5.

The significance F value and P-values indicate the validity of the test. The R-squared value although not so high is quite normal in human evaluations but in this case, can be confirmed by visual analysis of a scatter diagram.

Figure 2 clearly shows the relation between the two variables. Qualitative comments reinforce the interpretation of these numbers. Several positive aspects were highlighted by the students, such as, the possibility to approach real life representative problems and to solve them; the simplicity of using the game controls; the feeling of "reality" of the game; an entertaining, fresh approach to study school subjects. The game was found to be challenging and students appreciated the fact that they felt they had to put their minds at work in order to solve realistic problems and make logical connections. The mental and physical stimulation and the easiness on the development of practical skills was considered appealing by the students. There was also a positive feedback from the teachers who played the game as passionately as the students. They recognized the potential of eCity as an engineering promotion tool.

So, the analysis leads to the understanding that there is a relation between the enjoyment of such a

Table 5. Regression analysis values

Multiple R	R-Squared	Significance F	P-values		Coefficients	
0.6445	0.4154	2.12E-103	7.77E-05	2.1E-103	0.4814	0.8100

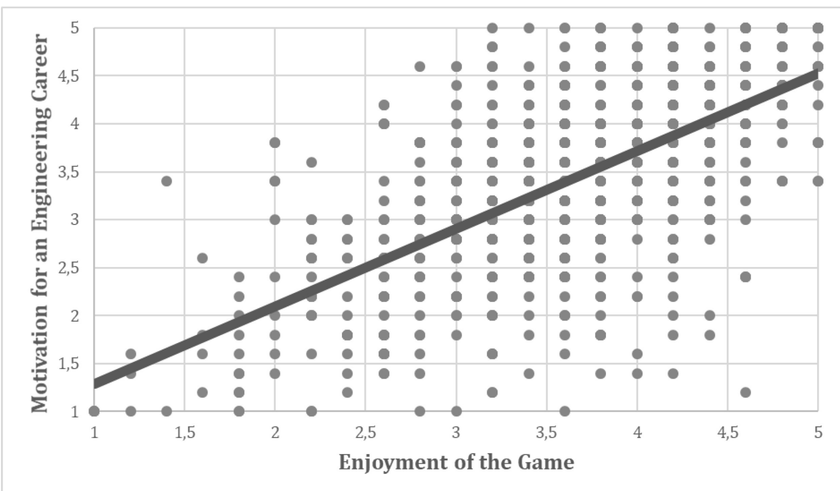

Fig. 2. Relation between the enjoyment in playing the game and the awareness and willingness in following an Engineering career.

Table 6. Linear regression analysis values according to age

Age	Multiple R	R-Squared	Significance F	P-values		Coefficients	
11–14	0.6632	0.4398	7.41E-28	0.0178	7.41E-28	0.5772	0.7928
15–19	0.6336	0.4015	1.32E-75	0.0012	1.32E-75	0.4618	0.8127

Table 7. Linear regression analysis values according to gender

Gender	Multiple R	R-Squared	Significance F	P-values		Coefficients	
Female	0.6368	0.4055	2.45E-37	0.00103	2.45E-37	0.6175	0.7649
Male	0.6391	0.4085	4.66E-65	0.0190	4.66E-65	0.3843	0.8390

Table 8. Linear regression analysis values according to location

Location	Multiple R	R-Squared	Significance F	P-values		Coefficients	
Turkey	0.5459	0.2980	2.44E-13	0.0004	2.44E-13	1.1885	0.6977
Italy	0.7465	0.5551	7.36E-26	0.7861	7.36E-26	0.0698	0.9156
Portugal	0.6279	0.3942	8.03E-18	0.8768	8.03E-18	-0.0599	0.9163
Spain (Vigo)	0.6820	0.4652	1.15E-15	0.2607	1.15E-15	0.3249	0.8398
Spain (Valencia)	0.5756	0.3313	1.63E-21	0.0221	1.63E-21	0.5798	0.7444
Greece	0.5938	0.35326	2.27E-10	0.0039	2.27E-10	1.1030	0.6808

game and the understanding and the willingness to follow an engineering career.

Concerning the other hypotheses, a similar study was conducted. For *H1.1: The impact of playing the eCity game in the understanding and willingness of following an engineering career is independent of the players' age,* the t-test (t = 2.703; p = 0.004) indicated that there was a significant statistical difference between the two groups. The regression analysis provided the results reported in Table 6.

Like the descriptive analysis already indicated, there is a higher impact of the game in younger students than in the older ones which means that this kind of initiative must be adopted as early as possible. In fact, from the qualitative comments, comments were positive, and the game was found to be attractive, interesting and motivating. Many students were interested in replaying the game and asked to download it to their personal computers or smartphones to use it in their free time. But, clearly, younger students showed more genuine enthusiasm about the game, asking for more time to play and to replay it at home. Students also commented that by providing a more detailed introduction to the game (a short video-tutorial was suggested) the satisfaction level of the students might improve. So, the analysis indicates that H1.2 does not stand and that there is in fact a difference in the impact produced by these type of games, depending on the age of the players.

In relation to H1.2: The eCity game can contribute to motivate students to follow an engineering career independently of their genre, the t-test (t = 3.579; p = 0.0002) indicates that there is a significant statistical difference between the two groups. The regression analysis provided the results reported in Table 7.

Curiously, and unlike in the descriptive analysis, there are no significant differences in the gender analysis. The detected correlation is the same for both groups. This might be interpreted as the stronger appeal of this type of games to male students correlates to an identical stronger orientation towards engineering. Therefore, a different type of games must be designed to motivate female students.

Concerning *H1.3: The eCity game can contribute to motivate students to follow an engineering career independently of the location*, it was not possible to get clear and valid results. A detailed analysis can be seen in Table 8.

The high p-values in Italy, Portugal and Spain and the lower correlation analysis in the other locations do not allow to provide an answer based on significant statistical analysis. Also, different existing conditions for the testing might have had a strong influence on some answers. In the interviews, it was possible to understand that a few technical problems in the laboratories and equipment used for the study might have given a less positive image of the game and therefore conditioned the game impact. For instance, some difficulties in handling the mouse were reported (the cursor was sometimes "slow" in responding to mouse movements, and some users commented it wasn't very intuitive to use).

In some countries during the testing the high school students were more interested in playing the game (e.g., Italy), whereas in others (e.g., Valencia and Portugal) students paid a lot of attention to the challenges during the whole experience. These students asked for more clarifications and made more suggestions, searching in many cases for solutions related to their choice of studies. Therefore, more extended studies are required to assess H1.3.

5. Conclusions

There are many reasons explaining the current low popularity of STEM and engineering among younger students. This is an issue that must be addressed as the growing shortage of engineering professionals is becoming a global threat to industrial growth. But solutions must be based on new and innovative tools that address and motivate the current generation of students.

eCity is a city-simulation video-game designed to motivate towards an engineering career by delivering a set of real-life problems and challenges. The game was tested with students enrolled in basic and secondary education and it was found to be attractive, interesting and motivating and considered to be a valid tool for the introduction to several engineering fields. Results also show that there is a correlation between the level of enjoyment of the game and the impact of the game in selecting an engineering career. Several positive aspects were highlighted by the students, such as, the possibility to approach real life representative problems and to solve them, the feeling of "reality" of the game, the challenging nature of the game and the problem-solving approach.

The best time to involve students in the use of this type of games seems to be at the late basic education, since in this period students start to address more complex and abstract problems. These students were genuinely interested in the game, seeing it as something they enjoyed. In terms of gender, the study allowed to conclude that female students were less impacted by the game than male students, which might have to do with the type of the game. Further studies are required to address this gender-issue.

The eCity game has since been embraced by the educational community, being published in several online repositories of educational material, such as Scientix, the Community for Science Education in Europe and on the EBA, the Ministry of Turkish National website with 8.2 million registered users. Nevertheless, it is clear that this type of tools must be conciliated with more high-level institutional strategies to allow for a systematic implementation.

Acknowledgements—This work has been supported by the European Commission through its Lifelong Learning Programme, KA3, Project eCity, ref. 543573-LLP-1-2013-1-PT-KA3-KA3MP. Authors would also like to thank Pascual Lahuerta for his work during the eCity testing in the University of Valencia.

References

1. OECD, *PISA 2012 results: what students know and can do—Student performance in mathematics, reading and science*, OECD Publishing, 2014.
2. M. Caprile, R. Palmén and P. Sanz and G. Dente, *Encouraging STEM studies*, European Parliament—Directorate General for Internal Policies, Brussels, 2015.
3. K. Yelamarthi, B. DeJong, T. Kaya, M. Prewett and D. Chen, Engaging Secondary School Teachers in Engineering Design: Lessons Learned and Assessment of a Research Experience for Teachers Program, *International Journal of Engineering Education*, **33**(5), 2017, pp. 1699–1709.
4. X. Chen and M. Soldner, *STEM attrition: college students' paths into and out of STEM fields, statistical analysis report*, 2013. [Online]. Available: http://nces.ed.gov/pubs2014/2014001rev.pdf [accessed 1 July 2016].
5. T. Snyder and S. Dillow, Digest of Education Statistics, 2012. NCES 2014–015, Nacional Center for Education Statistics, 2013.
6. I. Villanueva and L. Nadelson, Are We Preparing Our Students to Become Engineers of the Future or the Past?, *International Journal of Engineering Education*, **33**(2A), 2017, pp. 639–652.
7. P. Kutnick, Y. Chan and P. Lee, Engineering education opportunities, perceptions and career choice of secondary school students in Hong Kong SAR, China, in *ASEE Annual Conference Program: Final Conference Program and Proceedings*, 2012.
8. G. Cerinsek, T. Hribar, N. Glodez and S. Dolinsek, Which are my future career priorities and what influenced my choice of studying science, technology, engineering or mathematics? Some insights on educational choice—case of Slovenia, *International Journal of Science Education*, **35**(17), 2013, pp. 2999–3025.
9. A. Kumar, N. Randerson and E. Johnson, Engineering UK 2015. The State of Engineering, 2016. [Online]. Available: http://www.engineeringuk.com/EngineeringUK2015/EngUK_Report_2015_Interactive.pdf [accessed 1 July 2016].
10. I. Spectrum, Spectrum Forecasters STEM Survey Report, IEEE, 2013. [Online]. Available: http://spectrum.ieee.org/ns/pdfs/forecaster/SpectrumForecastersSTEMSurveyReport.pdf [accessed 25 July 2016].
11. [EEF, Improving the quality and quantity of graduate-level skills, EEF, 2014. [Online]. Available: https://www.eef.org.uk/resources-and-knowledge/research-and-intelligence/industry-reports/improving-the-quality-and-quantity-of-graduate-lev. [accessed July 1 2016].
12. J. Andrés Diaz Lantada, E. Munoz-Guijosa, J. Tanarro and J. Muñoz Sanz, Engineering Education for All: Strategies and Challenges, *International Journal of Engineering Education*, **32**(5B), 2017, pp. 2155–2171.
13. L. Jofre, J. Cordoba and L. Robert, Attracting Student Vocations into Engineering Careers, in *Proceedings of the IEEE Engineering Education Conference*, Madrid, Spain, 2010.
14. UNESCO, Engineering: issues, challenges and opportunities for development, 2010. [Online]. Available: http://unesdoc.unesco.org/images/0018/001897/189753e.pdf [accessed July 1 2016].
15. R. Batista and C. Vaz de Carvalho, Work in progress—learning through role play games, in *Proceedings of the 38th Annual Frontiers in Education Conference*, Saratoga Springs, NY, 2008.
16. S. Martin, G. Diaz, E. Sancristobal and R. Gil, New technology trends in education: Seven years of forecasts and convergence, *Computers & Education*, **57**(3), 2011, pp. 1893–1906.
17. D. Gouveia, D. Lopes and C. Vaz de Carvalho, Serious Gaming for Experiential Learning, in *Proceedings of FIE–IEEE Frontiers in Education Conference*, Rapid City, South Dakota, USA, 2011.
18. C. Vaz de Carvalho, Is Game-Based Learning Suitable for Engineering Education?, in, *Proceedings of the EDUCON*

2012—Third IEEE Global Engineering Education Conference, Marrakesh, Morocco, 2012.
19. eCity, "eCity," eCity Consortium, 2016. [Online]. Available: http://ecity-project.eu [accessed 13 July 2017].
20. A. Joyce, Stimulating interest in STEM careers among students in Europe: Supporting career choice and giving a more realistic view of STEM at work, 2014. [Online]. Available: http://www.educationandemployers.org/wp-content/uploads/2014/06/joyce_-_stimulating_interest_in_stem_careers_ among_students_in_europe.pdf [accessed July 13 2017].
21. J. Chen, S. Metcalf and M. Tutwiler, Motivation and beliefs about the nature of scientific knowledge within an immersive virtual ecosystems environment, *Journal of Contemporary Educational Psychology*, **39**(2), 2014, pp. 112–123.
22. Filament Games, Reach for the Sun, Filament Games, 2016. [Online]. Available: https://www.filamentlearning.com/products/plant-structure-and-processes-unit-reach-for-the-sun [accessed 14 July 2017].
23. GlassLab, SimCityEDU: Pollution Challenge!, 2013. [Online]. Available: https://www.glasslabgames.org/games/SC [accessed 14 July 2017].
24. MIT Media Lab, Scratch, MIT Media Lab, [Online]. Available: MIT Media Lab [accessed 14 July 2017].
25. E-line Media, Gamestar Mechanic, [Online]. Available: https://gamestarmechanic.com/ [accessed 14 July 2017].
26. Microsoft Research, Kodu, Microsoft Research, [Online]. Available: https://www.kodugamelab.com/ [accessed 14 July 2017].
27. engineering.com, [Online]. Available: http://www.engineering.com/. [accessed 14 July 2017].
28. IBM, TryEngineering, [Online]. Available: http://tryengineering.org/play-games [accessed 14 July 2017].
29. SpaceBOX, Engineering Games, [Online]. Available: http://engineering-games.net/ [accessed 14 July 2017].
30. Intelligent Energy Europe, EnerCities, [Online]. Available: http://www.enercities.eu/ [accessed 14 July 2017].
31. Genesis Energy, ElectroCity, Genesis Energy, [Online]. Available: http://www.electrocity.co.nz/. [accessed 14 July 2017].
32. Rhône-Alpes, Ecoville, [Online]. Available: https://www.ecovillelejeu.com/ [accessed 14 July 2017].
33. IBM, CityOne, [Online]. Available: http://www-01.ibm.com/software/solutions/soa/innov8/cityone/index.jsp [accessed 14 July 2017].
34. Education and Culture DG, [Online]. Available: http://ohmpro.org/envkids/ [accessed 14 July 2017].
35. M. Valdez, C. Ferreira, M. Martins and F. Barbosa, 3D virtual reality experiments to promote electrical engineering education, in *Proceedings of the Information Technology Based Higher Education and Training (ITHET) Conference*, 2015.
36. Department of Education USA, STEM 2026—A Vision for Innovation in STEM Education, September 2016. [Online]. Available: https://innovation.ed.gov/files/2016/09/AIR-STEM2026_Report_2016.pdf [accessed 14 July 2017].
37. Stanford Children's Health, Cognitive Development, 2017. [Online]. Available: http://www.stanfordchildrens.org/en/topic/default?id=cognitive-development-90-P01594 [accessed 19 July 2017].
38. CEDEFOP, A strategy for green skills? Briefing note, 2011. [Online]. Available: http://www.cedefop.europa.eu/EN/Files/9067_en.pdf [accessed July 26 2016].
39. E. Rohaan, R. Taconis e W. Jochems, Reviewing the relations between teachers' knowledge and pupil's attitude in the field of primary technology education, *International Journal of Technology and Design Education*, **20**, 2010, pp. 15–26.
40. F. Becker, Why don't young people want to become engineers? Rational reasons for disappointing decisions, *European Journal of Engineering Education*, **35**(4), pp. 349–366, 2010.

Carlos Vaz de Carvalho has a PhD degree in Technologies and Information Systems from the University of Minho, in Portugal. He is Associate Professor of the Computer Engineering Dep. of the Instituto Superior de Engenharia do Porto. From 2005 to 2014 he was Scientific Coordinator of the GILT (Graphics, Interaction and Learning Technologies) Research Group. He directed eight PhD theses and 30 Master in this area. Throughout his career he authored over 150 publications and communications on the subject, including more than ten books (as author and editor). Also noteworthy is the coordination of over 10 national and European projects and the participation in more than 25 other. Since 2014 he is Director of Virtual Campus Lda, a software company dedicated to educational technology (mainly games) and mobile application development.

Martín Llamas Nistal has a PhD degree in telecommunication from the Polytechnic University of Madrid, Spain. He has served as Vice Dean of the Higher Technical School of Telecommunication Engineers (1994–1997), and as head of the ICT Area (1999–2003), both in the University of Vigo. He is author or coauthor of more than 200 papers in peer-reviewed international refereed journals and conference proceedings and has directed and participated in several national and international research projects in telematics and technology enhanced learning fields. He is member of the Association for Computing Machinery (ACM), and Senior Member of the Institute of Electrical and Electronics Engineers (IEEE). He is currently Vice-President of IEEE ES for Publications, elected member of the Board of Governors, and member of the Strategic Planning Committee.

Manuel Caeiro-Rodríguez received his PhD in Telecommunications Engineering from the UVIGO in 2007. He is currently Associate Professor at the Department of Telematic Engineering, University of Vigo. He has received several awards by the W3C, NAE CASEE new faculty fellows and the IEEE Spanish Chapter of the Education Society. He has participated in 3 EU funded projects, 5 national projects and numerous research contracts. During 2012 and 2015 he has been the head of the TELGalicia research network involving 7 groups from Galicia, 3 more from the rest of Spain and 3 more from the rest of Europe. His current research interests include e-learning technologies and standards, semantic web, process-aware management systems and open educational resources.

Andrea Bianchi, degree in Philosophy, is a project manager and training consultant with more than 8 years of experience. Since 2008 he has been working as an expert in studies and researches in IVET and ECVET systems, training needs analysis and skills assessment in many strategic projects implemented at national and EU level.

Melani Hromin received her master's degree in Sociology and English Language and Literature. Since 2012 she has been managing international EU projects for young people in different topics like innovative education, inclusive learning, youth (un)employment, sustainable development, culture, art, sports.

Hariklia Tsalapatas has a PhD in Computer Engineering with a focus on the development of serious games for learning from the University of Thessaly. She has an MSc Degree in Computer Science from Rice University in Houston, TX. She has an MBA from London Business School. She has a bachelor's Degree from the University of Patras in Greece. She is engaged as a lecturer at the Electrical and Computer Engineering Department on Technology Enhanced Learning and other subjects. She has worked on over 22 R&D projects since 1997, 20 of which on behalf of UTH since 2000. She has published over 60 articles on technology enhanced learning since 2000.

Olivier Heidmann has a master's Degree in Parallel Computing from the Louis Pasteur University of Strasbourg, France. Since 2004, he participated either as technical lead or as a key software and service designer and developer in 15 different EC-funded projects, using ICT and web-based solutions to enhance teaching and learning methodologies and tools. He has published over 50 papers at international conferences over the past 8 years.

Alper Metin has BA from Hacettepe University, Department of English Language and Literature and has a master's degree from İstanbul University, Department of English Language and Literature. He has been working as an English teacher in public schools in Turkey for 15 years.