EnerCities, a Serious Game to Stimulate Sustainability and Energy Conservation: Preliminary Results

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Serious gaming is generally considered to be a powerful means to educate people. Using such games in order to influence the energy consumers of tomorrow –i.e. present-day secondary school students to become more environmentally friendly and conserve more energy at home– presents researchers and designers with a specific set of challenges. In addition to resorting desired effects on outcome variables, the game also has to appeal to people who are highly critical.

This paper presents some preliminary evaluation results of a serious game developed to increase awareness and attitudes relating to energy use in the household, in a number of European countries. Combining results from exploratory quantitative and qualitative pilot studies and quantitative field experiments, we come to the following conclusions: (serious) gaming in the field of sustainability and energy conservation is not common among students, as evidenced by extremely low percentages of reported use.

Furthermore, results clearly show that playing EnerCities increased awareness, and more positive attitudes towards some everyday-life energy-related behaviours.

1. Introduction

Sustainability and energy conservation at home are topics that are high on the agendas of many EU countries and have been implemented in educational programmes on multiple levels (primary school, secondary school, vocational level, bachelor's and master's level). Arguably, these two topics have a rather abstract and complex character. For instance, sustainability and energy conservation relate to many different behaviours on various levels, whose impact on energy consumption may not be immediately clear. On a consumer level, one could strive for sustainable living by selecting in-season vegetables only, abstain from using the car, insulate one's home, or wash at lower temperatures. At a governmental or societal level choices need to be made in which energy needs, emission levels and pollution, financial resources, etc. need to be balanced; money invested in wind turbines or solar energy facilities cannot go to housing projects, for instance. In our view, serious gaming is a potentially powerful tool, enabling youngsters to grasp the complexity of topics as sustainability and energy conservation and stimulating energy-conservation awareness, attitudes and behaviours of youngsters in a fun way, inside and outside of classrooms. This is why the EnerCities project was initiated; it involves the development of an online serious game to educate secondary school students, i.e. tomorrow's energy consumers, in this respect. This paper reflects on our findings from an exploration of the various energy-related games used by students, the effects of actually playing EnerCities on students' environmental awareness, and energy saving attitudes.

2. Household energy consumption and conservation

The need to inform, educate and inspire youngsters about sustainability, energy consumption (patterns) and energy conservation, is in line with national and European policies. By and large these prescribe a reduction of greenhouse gas emissions, most importantly of CO2, a reduction in energy consumption, stimulation of the development and implementation of renewable energy sources, and a decreased dependency on fossil fuels (European Commission, 2010).

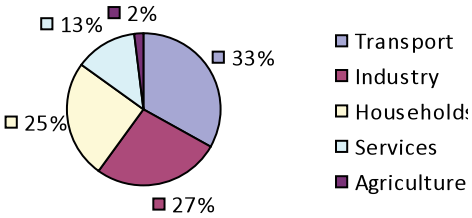

Figure 1: Total final energy consumption distribution in 2008 of the EU27 countries (total is 1169 Mtoe - million tonnes of oil equivalent) (Eurostat, 2010)

When we look at the current energy consumption figures in Europe (EU27; see Figure 1), it becomes clear that a considerable part of the total energy consumption, approximately 25 %, can be attributed to household consumption. In addition, Figure 2 shows that during the period of 1998 to 2008 the electricity consumption per dwelling for electrical appliances and lighting increased in almost all EU27 countries. Explanations can be found in the increased availability of electrical appliances in each home, both in terms of the number of different types appliances as well as the number per type (e.g. it has become more and more common to have more than one television or radio per household) and the expansion of adoption of the personal computer and internet. These trends counteract the overall energy efficiency improvements in the household sector during that same period, achieved for instance in space heating, water heating and cooking (see Figure 2). On a European level, the ambition is to substantially invest in and stimulate energy efficiency, as evidenced by Member States' expressed commitment to achieve a 20 % reduction in the consumption of primary energy by 2020 (European Commission, 2006: Action Plan for Energy Efficiency 2007-12 of the European Union).

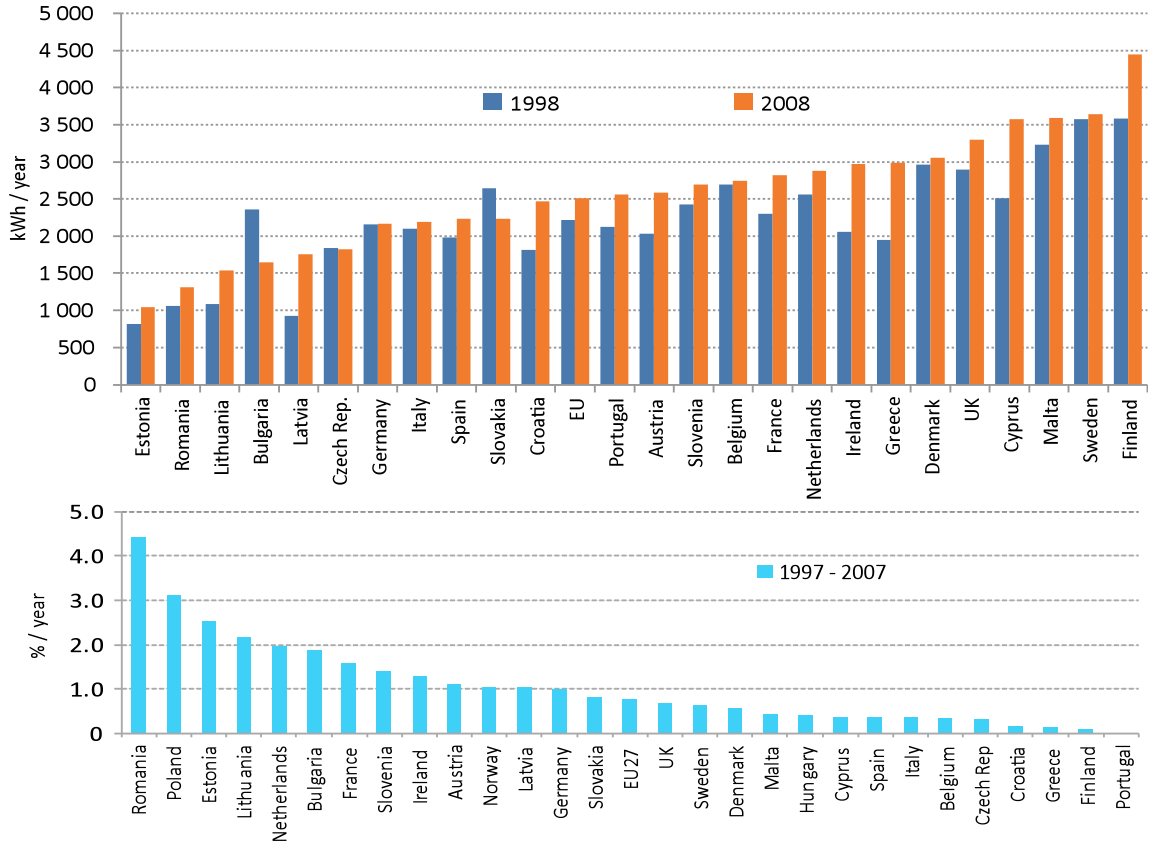

Figure 2: *Above* – electricity consumption per dwelling for electrical appliances and lighting (Odyssee, 2011); *below* – energy efficiency improvements in the household sector (Odyssee, 2011)

In order to stimulate household energy conservation, according to some the most cost-effective way to achieve energy savings (e.g. Bertoldi et al., 2000), intelligent education of youngsters is needed, focusing on increasing awareness of the role of energy in our society and energy consumption at home, and influence their (future) energy-related behaviours. At schools across Europe, substantial attention is devoted to sustainability, renewable energy and energy efficiency. Some projects are initiated locally, while others are more embedded in regional, national or European initiatives or frameworks like the initiative U4energy. This pan-European competition for both primary and secondary schools includes three competition categories: energy efficiency measures at school, best pedagogical actions to raise awareness on efficient energy use, and best awareness raising campaign on energy efficiency. Besides regular education programmes, new and innovative educational concepts are being developed to reach youngsters and involve them in sustainability and energy efficiency (e.g. Gustafsson et al., 2009). One of these concepts is serious gaming.

3. Serious games on sustainability, renewable energy or energy saving

Traditional education programmes have difficulties to adapt to the information processing styles, communication and social routines of young people. Typically, today's young people prefer visual information over textual, are cross-media oriented, play games (from casual games to MMORPGs - massively multiplayer online role-playing games) and are highly active on social network sites (Bennet et al., 2008). This is why education institutes would like to find ways to modernise their methods and instruments for knowledge transfer, students' skill development and enhancement. Serious games probably constitute more suitable learning tools due to their engaging character (e.g. Annetta, 2008; Ratan & Ritterfeld, 2009). Defined as "a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives" (Zyda, 2005; p. 26), they go beyond 'game-based learning' (Prensky, 2007) or 'elearning games' in that they also have the ambition to incorporate fun and enjoyment in the gaming experience while the learning elements are less overtly positioned in the game. An effective serious game should take into account intrinsic motivational ingredients like challenge, curiosity, fantasy, and control (Rieber, 1996).

Over the years, a variety of elearning games and serious games dealing with sustainability, energy efficiency and renewable energy have been developed and deployed. Some of these games are public-funded games (e.g. funded by the European Commission or national governments; e.g. EnerCities is co-funded by the European Commission Intelligent Energy Europe Programme), while others are industry-driven games that are (partly) initiated by companies (e.g. companies active in the energy sector such as Chevron). Examples are EnerCities (available in 6 languages), ElectroCity (English language), EfficienCity (English language), EnergyVille (English language), EcoVille (13 languages), Clim'Way (French and English language), BBC Climate Challenge (English language), Eco-Agents (24 languages), CEO2 Climate Game (English language) or even SimCity Societies (more than 20 languages). All these (free) online games have the ambition to reach young people and/or students and inform and inspire them about the social, economic and technological challenges related to sustainability, climate change, renewable energy or

Figure 3: Students playing EnerCities

energy efficiency. Not all games, however, have been able to appeal to 'digital natives' and to trigger them to stay online, game, absorb and learn. It seems that many elearning games and serious gaming dealing with sustainability, energy efficiency and renewable energy seem to have put fun and enjoyment less central in the game concept. Ideally, they should be in the first place games for enjoyment containing explicit or even implicit specific content instead of specific content looking for or transformed into game formats.

The serious game BBC Climate Challenge is rather text driven and the level of complexity seems to be more appropriate for bachelor and master students. ElectroCity has been available for some years and is quite popular. Nevertheless, ElectroCity, EnergyVille and EcoVille and others have to compete with more recent serious games such as EnerCities, the game central to this paper. It too focuses on young people, especially secondary school students, to stimulate their awareness about the balance of people, profit and planet and the relevance of renewable energy and energy saving. It attempts to appeal to the target groups, however, by taking into account their specific characteristics, needs and desires, both in terms of communication as well as gameplay. To be and stay attractive for young players, EnerCities has an up-to-date visual appearance, sound effects and music, and an advanced game engine for visualising 3D perspectives, 3D motion and animations. Moreover, gameplay takes place on a website (browser-based), which is also embedded in social media; users of Facebook can easily enter or re-enter the game from their particular social media platform (http://apps.Facebook.com/EnerCities), thus experiencing little or no barriers. The use of social media for dissipation of the game also allows gamers to post their gaming scores, thus enhancing gameplay experience and increasing the likelihood that gamers will return by creating an element of competition. A next phase for these serious games could be multiplayer variants to facilitate in-game interaction with others. However, research is suggested in terms of frameworks, guidelines, and processes for multi-user games with learning ambitions (Richter & Livingstone, 2011).

The serious game EnerCities (www.EnerCities.eu) and related educational materials are available for schools and individuals across Europe, in six different languages (Dutch, English, German, Greek, Slovenian, and Spanish). Large-scale usage of the game on schools started as from September 2010, and in the mean time more than 5,000 students have played it in a school setting (during regular lessons or special projects in the field of sustainability or energy; see Figure 3). The game is designed to be played on classroom computers with rather low specifications, preventing that EnerCities cannot be played on schools with less modern ICT infrastructures. EnerCities has won both national and international awards ('Best Learning Game 2010' according to European platform 'ENGAGE Quality Awards' and the Dutch game industry awarded EnerCities with the title 'Best Online Game 2010').

The EnerCities game starts with a small village and a small piece of land to build on. A drag-and-drop interface lets players build structures (e.g. residential and industrial areas, renewable / non-renewable energy sources, green zones) to expand the city (see Figure 4). The gamer needs to balance people, planet and profit while supplying the growing city with sufficient electricity, implementing energy conservation and CO2 emission measures and minimizing fossil fuel use. Each player's decision influences the scores for people, planet and profit. When done well, players receive more potential city space to expand their city and to utilise extra available game options. The game allows players to execute several strategies and see the results of their actions on the long term. The duration of the game is approximately 15-45 minutes, depending on the player's strategies.

4. Research results and reflections

A study was were conducted to ascertain whether playing the EnerCities game indeed offered a engaging environment encouraging learning about sustainability, renewable energy and energy conservation and, in particular, whether it positively influenced gamers' stance towards energy saving in their daily lives. During the rollout of EnerCities, a quantitative field-experiment was conducted to test differences in awareness concerning energy-related issues between a group who had actually played the EnerCities game and those who had not (i.e., a between-participants design).

Questionnaires were composed in six European languages (Dutch, English, German, Greek, Slovenian, and Spanish) and placed on www.EnergyQuestionnaire.eu. During the quantitative field-experiment (February 2011 – May 2011) more than 800 students from 5 countries filled in the online questionnaires. Additionally, during the rollout preparations dozens of students were asked to play and review EnerCities. Below, we would like to reflect on the following findings: energy games played by students, qualitative impressions of EnerCities on

The gameplay duration of EnerCities is 100 years as from 2010. Current 'year' is 2032.

In order to expand the city and to balance People, Profit and Planet of the growing city, several objects can be built: various types of residential areas (three types), industries (three variants), environmental objects (three types), objects to boost the citizens' well-being (three different types) and various type of renewable / non-renewable energy sources (nine different opt ons).

During the gameplay the environmental impact or energy efficiency of objects can be adjusted via a variety of measures like CO_2 taxes, insulation, energy eff cient light bulbs or thermal storage.

Available amount of energy, money and fossil fuels to play the game. Energy and money can be earned via the game. Fossil fuels can't be generated via the game. The girl is Alex; during the game she gives gameplay suggestions.

Level indicator of the game. The current level is 3 out of 4. In order to complete this level 100 houses need to be built. The current status is: 50 houses already built.

Overall scores and specific scores for economy, environment and well-being of the citizens.

Figure 4: Screenshot of EnerCities including basic information about the gameplay elements

students, effects of EnerCities on environmental awareness of students, and effects of EnerCities on energy saving attitudes.

4.1 Reflections about playing games on energy saving or renewable energy

Observations during the rollout of EnerCities showed that for teachers (mostly secondary schools and vocational education) gaming in the classroom and serious gaming are (still) new phenomena. This is in line with the study of the National Foundation for Educational Research (2009). It found that in a survey of 735 teachers (secondary schools) in 2009, 30 % said they had used games (designed primarily for entertainment) in the classroom for educational purposes and 58 % would be willing to do so in the future. Our data show that of a group of students from 8 European countries who never played EnerCities (N = 757; average age 18.3 years (SD = 8.1); 33 % female / 67 % male) only a fraction (4.5 %) indicated that he/she had played some sort of

How much fun did you have playing the game?	No fun: 14	Neutral: 14	Fun: 37
Did you find the game too easy, a good challenge or too hard?	Too easy: 18	Good challenge: 49	Too hard: 6
Compared to normal lessons, was it nice to play the EnerCities game in the classroom?	Not nice to play in the classroom: 7	Neutral: 13	Nice to play in the classroom: 36
Would you recommend this game to your friends	No: 22	Other / don't know: 7	Yes: 47
After playing the game, will you use less energy?	No: 24	Neutral / perhaps: 10	Yes: 40

Table 1: Students' answers on questions concerning the EnerCities game during rollout preparations; numbers indicate the number of times remarks occur in each category*

* N = 76; Slovenia: 6 respondents, Germany: 13, United Kingdom: 17, Greece: 19, and the Netherlands: 21

game dealing with the topic energy saving or renewable energy; of these, 0.4 % indicated to have played ElectroCity before, 0.3 % BBC Climate Challenge, 0.5 % other games like Build It Green: Back to the Beach and 3.3 % failing to specify a particular game. These findings were very similar to those in the group who did play EnerCities (N = 322; average age 15.1 years (SD = 3.3); 45 % female / 55 % male; from at least 6 European countries): 3.1 % had played ElectroCity, 0.6 % BBC Climate Challenge, 1.2 % other games, and 2.2 % reportedly being unable to specify a played game. We can safely conclude from these figures that (serious) gaming in the field of energy is not common among students, let alone in the classroom, but this diffusion process can speed up rapidly when teachers, specially those with early adopter characteristics, find the means and institutional support to further bring serious games to the classroom.

4.2 Quantitative and qualitative reflections on the EnerCities game by students

For quantitative and qualitative reflections on the EnerCities game by students during the preparations of the European rollout of EnerCities a limited online questionnaire was used, which a total of 76 students from 5 schools across Europe successfully completed. Results show that in principle these students were not negative about the EnerCities game's thematic focus (city building and balancing people, profit and planet), the gameplay (including levels and complexity), and the look and feel of the game (graphics, colouring, 3D perspectives and motion, menus and options). In general, the students liked the strategic nature of the game. Students were also aware of the need for balancing multiple parameters (e.g. economy, energy, environment) in the game. Some students indicated the goal of the game to be unclear to them. Most of the students found the game 'fun' to play, that the game offered a good challenge (both not too easy and not too difficult), that it was nice to play in the classroom, and that they would recommend it to their friends (see Table 1). A large part of the students indicated to have used less energy after they have played the game. Remark: attitudes towards energy-related behaviours (at home) are specifically tested during the earlier-mentioned two quantitative field-experiments. In response to the question *'What did you find out about energy saving and 'green energy' after playing the game?'* large numbers of the students were able to elaborate on energy and energy saving. Nevertheless, the students were also critical on the learning aspects of the game. Table 2 gives an impression of reactions. By and large, although these quantitative and qualitative results offer some suggestions for improvement, it appears that the current version of EnerCities meets the target group's critical criteria.

"After playing the game I found out that saving energy is helpful to all of us."
"I can not change anything, but WE could. So we have to work together."
"I don't feel that I have learned something new about energy saving and green energy, as the game is quite generic. It refers to the way of constructing a city by using renewable energy in terms of environmental and money costs, but does not give any information of how can we save energy our daily life."
"I didn't learn anything about that, I already knew."

Table 2: Impressions of reactions on 'What did you find out about energy saving and 'green energy' after playing the game?'

Also elearning and games enthusiasts have reviewed EnerCities, such as Van den Berg (2010) who concludes that EnerCities plays quite easy and can easily be implemented in lessons or homework assignments. In her opinion a disadvantage is that espe-

	Experimental Group*		Control Group*		Significance	
	M	*SD*	*M*	*SD*	*F (1, 651)*	*p*
I am interested in learning more about energy saving and 'green' energy	5.02	1.79	4.38	1.89	19.67	< .001
I am concerned about the environment	5.35	1.55	4.82	1.62	18.54	< .001
I am aware of the linkages between economy, energy usage and environment	5.00	1.51	4.39	1.53	26.36	< .001
I am aware that environment is more important than economy	5.06	1.56	4.59	1.73	13.25	< .001
I am aware that I should lower my own energy usage	5.24	1.79	4.81	1.72	9.76	< .002

* Experimental Group N = 325; Control Group N = 328; data gathering period: February 2011 – May 2011

Table 3: Means and standard deviations of environmental awareness for the experimental and control group, and significance of their differences (7-points scale; higher scores indicate more positive awareness)

cially experienced gamers may easily get bored. Mack (2010), on the other hand, expressed concern about the lack of clues and feedback within chosen scenarios by the player. Nevertheless, he finds the concept of EnerCities great and rather addicting. The earlier-mentioned 'Best Learning Game 2010' award indicates that elearning professionals and teachers recognise the methodological, didactical and technical aspects of EnerCities.

4.3 Reflections on the effects of EnerCities on environmental and energy awareness of students

The purpose of EnerCities is to stimulate the awareness and attitude of youngsters regarding sustainability and energy saving. We tested the differences in awareness concerning environmental and energy-related issues between the experimental group (EnerCities players) and the control group (students who did not play EnerCities) (average age 16.40 years (SD = 3.21); 36 % female / 64 % male; from 5 countries). To test whether playing the EnerCities game had increased awareness about energy conservation issues, as opposed to the control condition in which the game had not been played, the scores on five awareness items were inserted in a multivariate analysis of variance (MANOVA). This yielded a significant multivariate effect, F (5, 647) = 6.58, p < .001. Table 3 shows that for each of the five items a higher awareness score was found for the experimental group compared to the control group; univariate tests, also displayed in Table 3, indicated that for each item this difference was highly significant. These results clearly show that playing EnerCities increases the awareness on energy-related and environmental-related issues.

	Experimental Group*	
	M	*SD*
After playing the EnerCities game I was interested in learning more about energy saving and 'green' energy	4.30	1.79
Playing the Enercities game has increased my concern about the environment	4.29	1.56
Playing the Enercities game made me aware of the linkages between economy, energy usage and environment	3.95	1.59
Playing the EnerCities game made me aware that environment is more important than economy	4.02	1.47
Playing the EnerCities game made me aware that I should lower my own energy usage	3.91	1.63

* N = 119; data gathering period: September 2010 – January 2011

Table 4: Means and standard deviations of environmental awareness strongly related to the player's EnerCities experience (7-points scale; higher scores indicate more positive awareness)

Table 4 shows the absolute average environmental and energy awareness in relationship with the player's EnerCities experiences. It shows that respondents (84 % females / 16 % males; average age 17.79 years (SD = 1.97)) gave slightly lower item scores on the environmental awareness questions than the experimental group mentioned in Table 3. The difference could be found in the explicit mentioning of EnerCities in the questions, leading to more critical consideration and reflection of the respondents on the questions. On the other hand, in light of Aktamis' (2011) results, it could also be explained by the slight differences between the two pools of respondents, especially regarding the distributions of males and females (36 % female / 64 % male versus 84 % females / 16 % males). Further research is needed to filter a potential gender effect in relation to environmental and energy awareness.

4.4 Reflections on the effects of EnerCities on energy saving attitudes

To test the intervention effectiveness of the game on several energy-related attitudes, measurements of attitudes of the experimental and control group were compared in between-participants field experiment. The research results (Table 5; see De Vries & Knol, 2011, for a complete description and discussion) indicate two things. Playing the EnerCities game resulted in higher attitudes towards performing specific household behaviours that have consequences in terms of energy use, as indicated by a significant multivariate test of significance, F (4, 648) = 2.76, $p < .03$. Subsequent univariate tests showed participants' attitudes towards saving energy at home, towards turning off the TV (instead of using standby function), and towards taking shorter showers significant differences (see Table 5 for means, standard deviations and test results).

As indicated in Table 5 no significant differences regarding attitude towards switching off lights in unoccupied rooms were found. However, this attitude is already relatively high in both the experimental and control condition. This could be related to the salience of energy efficient lighting as a result of the discussions in popular media in recent years about the inefficiency of incandescent light bulbs, and the resulting phasing out of these light sources. Possibly, this may have caused higher a-priory attitudes towards light regulation as a means to reduce energy, leaving little room for an additional increase by means of our experimental manipulation.

We would like to remark that regarding an actual change in energy-related behaviours at home factors such as existing habit patterns play an important role (De Vries et al., 2011). Although we signalise significant positive changes in energy-related attitudes, for the moment we are less able to reflect on actual changes of energy-related household behaviours of the students who played EnerCities.

As elaborated in De Vries & Knol (2011), it is interesting to see that the virtual city-planning in EnerCities (macro level planning and action) can have effects on 'real world' micro level behaviours of the students, namely energy-related behaviours in the household. Apparently, members of our target group experienced little difficulty in connecting the one with the other.

	Experimental Group*		Control Group*		Significance**	
	M	*SD*	*M*	*SD*	*F (1, 651)*	*p*
Attitude towards saving energy at home	6.19	1.16	5.96	1.30	5.59	.018
Attitude towards switching off lights in unoccupied rooms	6.31	1.11	6.18	1.11	2.06	Ns.
Attitude towards turning off TV instead of using standby	5.95	1.28	5.73	1.44	4.44	.036
Attitude towards taking shorter showers	4.82	1.71	4.41	1.82	8.90	.003

* Experimental Group N = 325; Control Group N = 328; data gathering period: February 2011 – May 2011
** Ns. = not significant

Table 5: Means and standard deviations of attitudes towards energy-related behaviours for the experimental and control group, and significance of their differences (7-points scale; higher scores indicate more positive awareness)

5. Conclusion

This paper presents some preliminary results of evaluation and effectiveness studies regarding the serious game EnerCities. A number of studies, exploratory, quantitative and qualitative pilot studies as well as quantitative within-participants and between-participants field experiments, yield findings that are relevant to those interested in promoting sustainability in general and household energy conservation in particular among especially students, as well as those interested in optimal design of serious games.

Firstly, (serious) gaming in the field of energy conservation and sustainability is not common among students, as evidenced by extremely low percentages of reported use, despite of a range of games being currently available. In addition, the people teaching these students generally think that serious games are suitable educational tools, and also appear to be willing to start using them in class. Moreover, implementation of the current serious game, EnerCities, has resulted in positive effects. Not only did students and practitioners react largely positively, the experimental study has shown clear effects on important outcome variables. First, the field experiment showed higher environmental and energy-related awareness ratings for students who had played EnerCities compared to those who had not. Secondly, the field experiment showed that attitudes towards energy-related behaviours in the household were generally more positive for students who had played EnerCities compared to the control group members.

Although we are quite confident in saying that the serious game EnerCities constitutes a positive intervention regarding environmental and energy-related awareness and attitudes towards various energy-related household behaviours, we should not exclude the possibly positive influences of other variables pertaining to the experimental settings than the mere game itself. For example, on some schools the experimental group played EnerCities as a part of a school project on sustainability with the direct involvement of inspired teachers, while other schools organised special EnerCities days with EnerCities gaming competitions among classes and special lectures. The social context in which students interacted with the game may also in part have been responsible for these positive results. However, it can be said that the EnerCities game operated in many cases as the eye-catcher to inspire students about sustainability and energy saving.

Serious games on sustainability, renewable energy and energy efficiency, such as EnerCities, can and will have their roles in inspiring students and stimulate 'experimental learning by gaming'. As shown in this paper, serious games actually facilitate learning processes of students on sustainability and energy conservation at home looking at the resultant of this learning process: higher awareness levels regarding energy-related topics and higher attitudes towards performing specific household behaviours that have positive consequences in terms of energy use. We sincerely hope that these positive results inspire the various stakeholders, such as policymakers with regard to digital education and environmental education, school managers, and last but not least, teachers to put the use of game-based learning on sustainability in educational programmes high on the agendas of secondary educations.

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