Design 3D on-line gaming environment for learning how to design green buildings

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Abstract

This paper presents an approach for using e-learning to design a training environment for both students and professionals to learn 'how to design Green Buildings' developed as part of the D4E European project. The idea of the training environment is to enable users to learn individually or collectively through a 'team space' to design energy efficient buildings. An overview of various learning models and theories has been undertaken to understand how people learn. Amongst these, Constructivism and Humanism theories were selected as the most appropriate theories for this particular task and were used to define a number of learning elements required to foster a learning attitude. This work led to the creation of the D4E learning framework which identified, in addition to the learning elements, a number of skills that learners acquire from using such a training environment as they socially interact with one another through the game. Moreover, and in order to promote such learning elements, the concept flow was used to provide an interactive experience for the players to evoke a positive experience.

1. Introduction

On-line learning is increasingly being used as a training environment in professional organisations to enhance staff knowledge and skills, and amongst academic institutions (Cobb, 2013) offering on-line education. There is no doubt that the advanced development of computers, technologies and communication is affecting learning by providing new tools to enhance it. This is evident in the continued increase in the number of educators and organisations making use of virtual worlds in teaching programmes as well as in creating learning activities (Williams et al., 2011).

There are various types of technologies that can be used to support on-line learning making it available for users from any place and at any time using various platforms, tablets and mobile devices. Among these technologies, gamification has been specified as a widespread tool that incorporates elements of game play in a nongame situation (Prince, 2013) and is increasingly being used to engage learners to accomplish various tasks.

This work presents the approach used in the D4E project to design learning modules within the 3D on-line gaming environment. These modules are: new build, neighbourhood and retrofit and maintenance. For each module, a number of learning outcomes were defined with a list of activities, specific tasks and tutorials. In addition, an energy- efficient model was utilised to provide the appropriate content for these learning modules.

2. Related work

Online gaming, online learning or e-learning platforms generally have two purposes, as demonstrated within European projects. The first one is to teach and train the users in order to achieve a certain set of skills. Regardless of the research domain, projects such as ARISTOTELE or ALICE tend to create effective, collaborative online learning environments and to encourage users through the gaming aspect. TRAINHY-PROF and DIBANET aim to educate post-graduates comprehensively in energy technologies such as fuel cells and hydrogen. Target groups vary widely such as general employees, disadvantaged persons (users of the LITERACY project) or schools (users of the METAFORA project). The second purpose, which is often used in the energy domain, is to change human behaviour in order to achieve a more efficient or effective way of working, living, and learning. The E-GOMOTION project for example provides learning material for secondary school students to take part in a competition for the development of new mobility concepts for their local neighbourhood. The BEEM-UP project (ACCIONA) has provided as part of the awareness and dissemination plan training material and e-learning modules which are openly available on the internet. It is targeted at designers, engineers and the general public who wish to create a greener environment and it teaches how to communicate and collaborate with tenants in order to build sustainable buildings. A very modern approach is the usage of mobile technologies and smartphone applications such as the EnergyLife app, which was developed through the BEAWARE project. This app integrates home appliances fitted with wireless sensors to provide the user with an interesting reality-near experience to raise awareness concerning energy efficiency in their own buildings.

A review of current European projects confirms the interest in online learning as an effective approach in raising awareness in the energy domain especially among building owners, designers, engineers and occupants, and provides further good examples of building such platforms. The D4E project extends the above developments to design a 3D on-line gaming environment that provides its users with a holistic view on designing 'Green Buildings'. This is achieved by covering the aspects of new design and neighbourhoods together with retrofit and maintenance.

3. Learning models and theories

There is an abundance of models and frameworks within the literature that address how people learn such as Behaviourism, Cognitivism, Constructivism, Design-Based and Humanism (http://www.learning-theories.com). Since these models are interlinked in one way or another, this section starts with an overview of these models providing a brief description of the use of each model before selecting the most appropriate one and applying its use in designing the 3D gaming environment.

The Behaviourism learning theory is usually employed for developing training sessions with a focus on improving user behaviour since it operates on stimulus-response (Skinner, 1954, Thordike, 1911). This paradigm was later replaced with the Cognitivism theory in the 1960s, focusing on the mental and memory processes in the pursuit of information and knowledge, with the learner viewed as an information processor (Gagne and Briggs, 1979, Moore and Fitz, 1993, Piaget, 1926). The Constructivism paradigm views learning as an active and constructive process, focusing on the learner as the most important element in the education process (Thanasoulas, 2002). Another paradigm is the Design-Based Research Methods (DBR) which aims to uncover the relationship between educational theory, designed artefact and practice (Brown et al., 1989). Humanism is another paradigm that has a focus on the learner considering individual motivation as a key to obtaining knowledge and improving the learner's experience.

Since this work is about creating a 3D on-line gaming environment for green building training, two theories have been selected here for their great emphasis on the learner; Constructivism and Humanism. Given that the Constructivism theory incorporates an active and constructive learning process, it could well be utilised as the main model/paradigm to structure and design the various learning activities and tasks within the gaming environment to enable users to construct and create their knowledge on their own, without the assistance of instructors and teachers. By solving problems and finding solutions, learners can build up their understanding and conceptualisations independently (Thanasoulas, 2002). In such a way the Constructivism theory focuses on supporting learners whereby new information builds upon previous knowledge to improve the learner's experience (Resnick, 1987). The Humanism learning theory complements the Constructivism one since it offers a process of gaining knowledge based on individual experiences through the learning environment, whereby the learner forms his/her goals and performs activities to expand his/her potential and knowledge (Taylor and Hamdy, 2013).

3.1. Learning elements

Learning theories are useful in identifying significant elements that could be used to define a framework to structure and design the game's activities and its challenges. In addition to knowledge and skills, effective learning requires specific attitudes (Van Merriënboer and Kirschner, 2012). Based on both the Constructivism and the Humanism theories, learning attitude requires three elements to enhance a learner's capability to develop their knowledge and ability. These are: autonomous learning, curiosity and motivation.

According to Moore (Moore, 1973), independent learning is about 'what students learn and how they learn'. Curiosity, which is the second element identified here, is regarded as a key component for fostering creativity and subsequently enhancing learning (Arnone, 2003). According to Arnone (Arnone, 2003), a number of elements are required to enhance the learner's curiosity. These elements are: incongruity, contradiction, novelty, surprise, complexity and uncertainty. Such elements are to be taken into consideration when designing the game and its activities. Motivation, as the third element identified here, has an important impact on all phases of learning and achievement (Schunk, 2012) and can be defined according to the Longman Dictionary as 'eagerness and willingness to do something'.

The 3D on-line gaming environment should incorporate a user-oriented design in order to embrace the above three learning elements into its design with a focus on providing an interactive experience for the end-user to evoke positive experiences (Chen, 2007). To achieve this, we need to make a reference to the concept flow in positive psychology by Csikszentmihalyi (Csikszentmihalyi, 1990) which represents the feeling of complete and energised focus in an activity with a high level of enjoyment and fulfilment (Csikszentmihalyi, 2002). In his research, Csikszentmihalyi identified eight major components of flow. These are: challenging activity requiring skills, merging action and awareness, clear goals, direct but immediate feedback, concentration on the task at hand, sense of control, loss of self-consciousness and alerted sense of time.

Against this background the 3D on-line gaming environment will include as many as possible of the above flow components to deliver instantaneous, accessible sensory feedback while offering clear goals to the players to accomplish their specific tasks.

3.2. Group processes and motivation

Since the 3D on-line gaming environment for green building training has an element of collaboration with a focus on community learning, a discussion of group work would not be

complete without a consideration of the processes that groups go through and the need to motivate them. Tuckman (Tuckman, 1965) established that groups usually go through four stages from their formation, which has important implications for the study of the group and its activities. These stages are:

- Stage 1 Forming: At first, there is some anxiety among the members of the group, as they are dependent on the leader and they have to find out what behaviour is acceptable.
- Stage 2 Storming: There is conflict between sub-groups and rebellion against the leader. Members of the group resist their leader and question the relations and functions within the group.
- Stage 3 Norming: The group begins to develop a sort of cohesion. Members of the group begin to support each other. At this stage, there is co-operation and open exchange of views and feelings about their roles and each other.
- Stage 4 Performing: Most problems are resolved and there is a great deal of interpersonal activity. Everyone is devoted to completing the tasks they have been assigned.

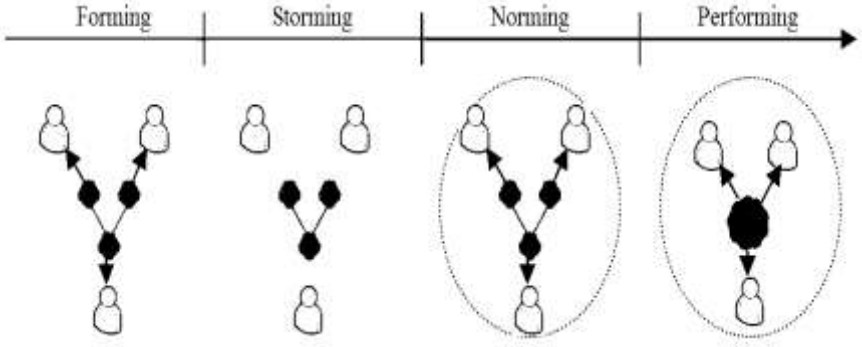

Figure 1: Group building process according to Tuckman

Experience shows that almost every group goes through these four (or even more) stages until it reaches stability and consequently taps into its potential. Against this background, the D4E learning framework will be designed to incorporate the learning factors discussed in the previous section with a consideration of group processes to foster collaboration and motivational strategies.

3.3. D4E learning framework for the 3D on-line gaming environment

The previous sections provided a background and a theoretical foundation to define a learning framework for the D4E project (Figure **2**). This learning framework will be used to design the 3D on-line gaming environment for "Green Building" training. The framework encapsulates the outcome of the previous sections and combines the learning factors required for creating a learning attitude and the skills that learners would acquire from using such a learning-based environment while collaborating in a social and interactive way. The D4E learning framework comprises the following:

- Learning elements: as explained previously, three elements were identified to create learning attitude: autonomous learning, curiosity and motivation. Grow's model (Grow, 1991) identifies four levels of learning as Dependant, Interested, Involved and Self-directed. For the nature of this tool, the autonomous learning will focus on the self-directed level where learners are able, willing and confident to make decisions by themselves. To achieve this, the on-line gaming environment will provide the learners sufficient learning material to assist them in making their decisions thus supporting independent learning. Curiosity was defined as a second learning factor that enhances learning. To achieve this, the tutorials and learning material provided in the on-line

gaming environment will be structured in a way to contain an element of surprise and possibly a degree of contradiction and uncertainty to enhance the learner's curiosity. This will be featured through 'what-if scenarios' activities that the learners will conduct. Motivation has been identified as the third learning factor in the D4E learning framework based on both the Constructivism and Humanism theories to promote independent and self-directed learning. To foster motivation, the flow concept discussed earlier on will be used in structuring the various tasks of the on-line tool providing an element of fun.

- Cognitive: this aspect concerns the skills that learners will acquire from using the 3D on-line gaming environment. Apart from enhancing their knowledge and experience of designing "Green Buildings", the gaming environment will provide users with the appropriate learning material with a high level of information covering a variety of knowledge fields such as issues required for creating a holistic design, environmental issues, energy systems, technologies and so on. The cognitive aspect focuses on acquiring information and enhancing understanding during the learning process to help the learner build his/her knowledge effectively. To ensure effective performance, the cognitive aspect should foster critical thinking and problem- solving. The critical thinking element involves a high level of information use rather than collecting data. It involves a variety of fields that contribute to knowledge (Gerber and Scott, 2011). Moreover, critical thinking involves appropriate reasoning to determine whether or not a particular claim is true (Moore and Parker, 2009). Problem-solving involves the use of knowledge and information with support from critical thinking to create a solution (Huang et al., 2010).
- Social interaction: to acquire the above mentioned skills that would enable the learners to create their knowledge successfully, the 3D on-line gaming environment will provide the users with a 'team space' to enable architects to collaborate with clients and other design team members when required to collectively make better informed decisions and reach optimised energy solutions.

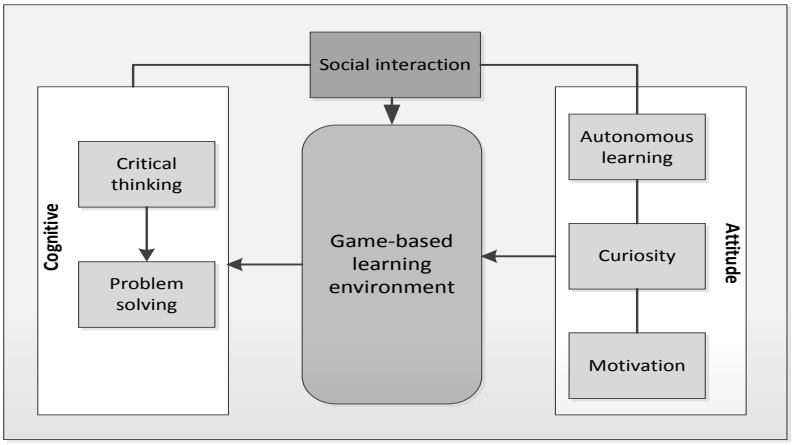

Figure 2: The D4E learning framework identifying specific learning elements and skills

4. Overall approach

As mentioned previously, in order to provide the game users with a holistic view on designing 'Green Buildings', the learning modules within the 3D on-line gaming environment were structured around the three scenarios identified in the project to cover the aspects of new design and neighbourhood together with retrofit and maintenance. These learning modules are:

- New-build learning module: The learning outcome and content will focus on environmental aspects [examples may include weather, orientation, material, openings and so on].
- Neighbourhood learning module: The learning outcome and content will focus on energy systems [examples may include energy systems and energy technologies].
- Retrofit and maintenance learning module: The learning outcome and content will focus on the use of maintenance and operational data to propose retrofit solutions [examples may include: occupancy type, nature of activity and user behaviour].

Figure **3** represents the overall approach used in developing a path for designing the 3D on-line gaming environment. Each one of the above learning modules will have specific learning objectives, activities and tasks which will be used to design the tutorials required for implementing the gaming environment. The next sub-section discusses the application of an energy-efficient model to structure the content of these learning modules.

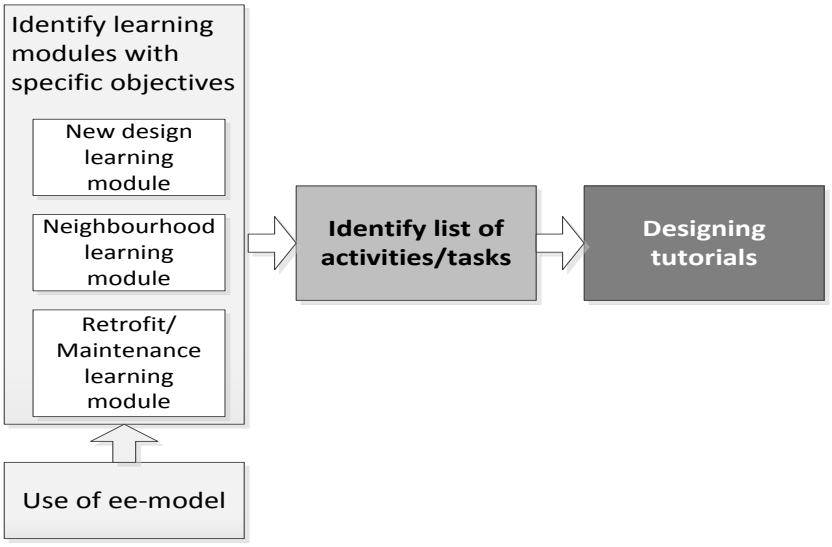

Figure 3: Overall approach for building the 3D on-line gaming environment

4.1. Use of the energy-efficient model

To integrate the above three learning modules in a single environment, an energy efficient model was utilised. The ee-model (Figure 4) will enable users to learn about designing energy efficient buildings taking a holistic view of integrating a single building design into a neighbourhood with respect to operational issues and user behaviour.

The new design learning module will provide architects and other game users with the opportunity to learn about the environmental and climate variables that will influence building design and energy consumption. Examples of these variables may include site micro-climate; geographic location, building surroundings, open spaces and building orientation which could well have an impact on daylight-shadowing. Other variables may include facade U-value, glazing ratio, external window U-value, external window G-value, and ventilation options. The analysis of climate change may include the following variables: temperature, precipitation, wind, radiation balance, potential evaporation and climatic water balance.

The neighbourhood learning module will focus on green buildings in neighbourhood systems (GBNS). The game users will learn concerning considering a cluster of buildings as an energy system where buildings can optimally interact with each other through smart grid technologies (Marzban et al., 2013) (Marzban, 2015). Moreover, the neighbourhood tutorial within the 3D on-line gaming environment will provide architects and other game users with

information on various types of energy systems such as heat, power, cooling. This will enable users to learn about defining an approach to achieve a share of energy resources inside GBNS in a sustainable way.

The retrofit and maintenance learning module within the 3D on-line gaming environment will provide the game users with the opportunity to better understand the impact of taking occupant behaviour into consideration in order to achieve energy efficient buildings (Day and Gunderson, 2015, Kashif et al., 2013, Lopes et al., 2012, Nguyen and Aiello, 2013). More specifically, game users will learn that (1) improper building use can cause a great waste of energy (Guerra Santin, 2013, Masoso and Grobler, 2010) and (2) a user-centred building control strategy can significantly contribute to reducing building energy consumption (Klein et al., 2012, Yang and Wang, 2013).

In this context, it is important to highlight the fact that the background literature and extensive content on each one of these three aspects will be available to the users in a variety of ways. Some of the learning material will be provided through conducting a number of activities and tasks while others will be offered through the use of educational videos or on-line reading. Such diversity will assist in achieving the learning elements required to create a learning attitude (autonomous, curiosity and motivation).

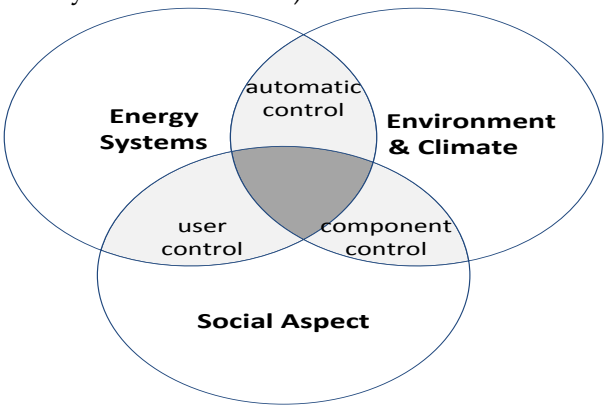

Figure 4: Use of the ee-model to structure the activities and tasks of the gaming environment

4.2. Game users

An initial enquiry took place with the D4E architects to firstly define potential users of the 3D on-line gaming environment and secondly to specify their requirements. The outcome of this inquest identified architects as the main user group for such an environment. However, the 3D on-line gaming environment could be extended in the future to other members of the design team such as energy experts, mechanical engineers and others since it provides community learning and a team space for collaboration.

In parallel, another enquiry took place with academics in the School of the Built Environment (SOBE) of the University of Salford to explore the potential of using the 3D on-line gaming environment in teaching architectural or other related subjects. Such discussions revealed the possibility of using the 3D on-line gaming environment in teaching architectural courses such as 'Performance Modelling' and MDP2 (Multidisciplinary Project) both of which are delivered to second year students. This includes the game to provide users with a knowledge and understanding of integrated and collaborative design strategies and to demonstrate a systematic understanding of the profession of architecture and its role.

The current 3D on-line gaming environment will initially be designed for two users to play the game taking the roles of an architect and a client. However, this could well be extended

in the future to provide a multi-user environment for other players to join in representing an energy expert, an HVAC engineer, an electrical engineer and so on.

5. Design of the 3D on-line gaming environment

This section describes the design of the 3D on-line environment. The following sub-sections provide an overview of each module including a set of activities and tasks analysing how these tasks can fulfil the D4E learning framework identified earlier on.

Prior to starting the game, each user needs to create an account to enable him/her to use the game. Prior to playing the game, users are directed to familiarise themselves with the background information provided in the gaming environment which will be structured around the themes of the learning modules.

5.1. New build learning module

The first learning module is about designing a new building. Since the main aim of this learning module is to develop an understanding of the impact of using various passive solutions on reducing energy demand and cost, players will use the various functionalities provided within the game-based environment to explore individually and/or collaboratively through the 'team space' how to make better informed energy related decisions which will result in designing more energy efficient buildings. More specifically, a number of learning outcomes can be identified:

- To explore the impact of using different materials on energy consumption.
- To explore the impact of a building's orientation on energy consumption.
- To explore the impact of glazing ratio on energy consumption.
- To explore the impact of any of the above variables on cost.
- To analyse various design alternatives and achieve better informed decisions collaboratively.

The following table summarises the tutorial that learners go through to design a new building. Based on the client's brief, the architect should design an energy efficient residential building that consists of the following spaces: entrance, living room, kitchen, bedroom and a bathroom. The players will use the 3D on-line gaming environment to explore the impact of various design solutions on energy performance and cost. More specifically, the game's users could make use of the following set of activities as a guideline to perform their specific tasks:

Activity	Task	Purpose and link to D4E learning framework
Improve current design (architect only)	Explore building orientation Explore use of material Explore glazing ratio	Activities are structured to create an autonomous/independent learning attitude through conducting a number of specific tasks. Providing a variety of options for the users to investigate within these tasks will offer an element of fun to foster curiosity and encourage users to explore other alternatives.
Conduct building performance (architect only)	Conduct initial building performance Make reference to indicators and KPIs Finalise design alternative 1	Once the users get a value for their design to assess it against a set of indicators, KPIs and so on, the 3D on-line gaming environment tool will provide them with some learning material (in the form of video clips, talks, on-line reading material and so on). The use of multimedia in making learning material available for the users will motivate the users and foster their curiosity to find out more through using such training environment.
Explore what-if-scenarios (architect only)	Change various parameters (material, orientation, glazing) Conduct initial building performance Finalise design alternative 2 Create other alternatives if required	Activities are structured to create an independent learning attitude through a number of specified tasks. Providing a variety of options for the users to investigate what-if-scenarios will advance their curiosity as they explore other alternatives. In addition, such tasks will enable users to develop critical thinking by exploring a number of what-if-scenarios and subsequently improve their problem-solving skills.
Review design alternatives (between architect and client)	Review design alternatives collaboratively Selection of design alternatives	The set of activity and tasks will encourage social interaction amongst the players to analyse and discuss various design alternatives and the decisions made.

Table 1: Activities, tasks and purpose of the new build learning module

5.2. Neighbourhood learning module

The second learning module concerns extending the single building design to a neighbourhood. Since the main aim of this learning module is explore the initiative of green buildings in neighbourhood systems (GBNS), players will use the various functionalities provided within the game-based environment to explore individually and/or collaboratively through the 'team space' how to make better informed energy related decisions which will result in designing more energy efficient neighbourhoods. More specifically, a number of learning outcomes can be identified:

- To understand the concept of green buildings in neighbourhood systems (GBNS).
- To better understand energy technologies.
- To learn about considering buildings as energy systems to make better informed energy related decisions about the neighbourhood.
- To learn about the use of distributed energy systems instead of independent ones.
- To analyse various GBNS and achieve better informed decisions collaboratively.

The following table summarises the tutorial that learners go through to extend their design to the neighbourhood. This learning module contains features applicable to the option of new design as well as retrofit and maintenance. Based on the client's brief, the architect should

improve the energy efficiency and cost of a residential building that consists of the following spaces: entrance, living room, kitchen, bedroom and a bathroom by considering alternative energy systems and technologies available in the neighbourhood. The players will use the 3D on-line gaming environment to explore the concept of GBNS. More specifically, the game's users could make use of the following set of activities as a guideline to perform their specific tasks:

Activity	Task	Purpose and link to D4E learning framework
Extend current design to the neighbourhood (architect only)	Find out information about various issues within the neighbourhood that could have an impact on a single building design Find out information about possible ways to consider buildings as energy systems (cluster of buildings instead of a single ones)	Activities are structured to create an autonomous/independent learning attitude through conducting a number of specific tasks. Providing a variety of options (in this case on energy systems and technologies) for the users to investigate within these tasks will offer an element of fun to foster curiosity and encourage users to explore other alternatives.
Conduct energy matching at neighbourhood level (architect only)	Conduct energy matching at neighbourhood level Make reference to indicators and KPIs Finalise design alternative 1	Once the users get a value for their design to assess it against a set of indicators, KPIs and so on, the 3D on-line gaming environment tool will provide them with some learning material (in the form of video clips, talks, on-line reading material and so on). The use of multimedia in making learning material available for the users will motivate the users and foster their curiosity to find out more through using such training environment.
Explore what-if-scenarios at neighbourhood level (architect only)	Use different energy technologies available within the neighbourhood Conduct energy matching at neighbourhood level Finalise design alternative 2 Create other alternatives if required	Activities are structured to create an independent learning attitude through a number of specified tasks. Providing a variety of options for the users to investigate will advance their curiosity as they explore other alternatives. In addition, such tasks will enable users to develop critical thinking by exploring a number of what-if-scenarios and subsequently improve their problem-solving skills.
Review design alternatives at neighbourhood level (between architect and client)	Review design alternatives collaboratively Selection of design alternatives	The set of activity and tasks will encourage social interaction amongst the players to analyse and discuss various design alternatives and the decisions made.

Table 2: Activities, tasks and purpose of the neighbourhood learning module

5.3. Retrofit and maintenance learning module

The third learning module is to investigate the use of maintenance and operational data to propose retrofit solutions. Since the main aim of this learning module is to develop an understanding of using operational and maintenance data to reduce energy demand and cost during operation, players will use the various functionalities provided within the game-based environment to explore individually and/or collaboratively through the 'team space' how to make better informed decisions relating to retrofit and maintenance. It is worthwhile emphasising that this exercise will be very similar to the new design learning module with the main difference relating to providing the users with an existing 3D building model that has

some operational issues relating to energy performance and/or cost issues. Furthermore, users could be provided with some social data about the users to take into consideration while performing the tasks of this learning module. More specifically, a number of learning outcomes can be identified:

- To explore the impact of using different materials on energy consumption during retrofit/maintenance.
- To learn about the impact of social, and in particular user, behavioural aspects on design during retrofit/maintenance.
- To explore the impact of glazing ratio on energy consumption during retrofit/maintenance.
- To explore the impact of any of the above variables on cost during retrofit/maintenance.
- To analyse various design alternatives and achieve better informed decisions relating to retrofit and maintenance collaboratively.

The following table summarises the tutorial that learners go through to explore the options of retrofit and maintenance during operation. In this module, users will be provided with a 3D model and operational data of a building that has some operational issues that need improving. Based on the client's brief, the architect should improve the energy efficiency and cost of a residential building that consists of the following spaces: entrance, living room, kitchen, bedroom and a bathroom. The players will use the 3D on-line gaming environment to explore how to improve energy performance and reduce operational cost. More specifically, the game's users could make use of the following set of activities as a guideline to perform their specific tasks:

Activity	Task	Purpose and link to D4E learning framework
Improve current design during operation (architect only)	Analyse current operational data Explore use of material Explore glazing ratio Analyse social data such as user behaviour	Activities are structured to create an autonomous/independent learning attitude through conducting a number of specific tasks. Providing a variety of options for the users to investigate within these tasks will offer an element of fun to foster curiosity and encourage uses to explore other alternatives.
Conduct building performance during operation (architect only)	Conduct initial building performance Make reference to indicators and KPIs Finalise design alternative 1	Once the users get a value for their design to assess it against a set of indicators, KPIs and so on, the 3D on-line gaming environment tool will provide them with some learning material (in the form of video clips, talks, on-line reading material and so on). The use of multimedia in making learning material available for the users will motivate the users and foster their curiosity to find out more from using such training environment.
Explore what-if-scenarios during operation (architect only)	Change various parameters (such as material and glazing) Conduct initial building performance Finalise design alternative 2 Create other alternatives if required	Activities are structured to create an independent learning attitude through a number of specified tasks. Providing a variety of options for the users to investigate will advance their curiosity as they explore other alternatives. In addition, such tasks will enable users to develop critical thinking by exploring a number of what-if-scenarios and subsequently improve their problem-solving skills.
Review design alternatives during operation (between architect and client	Review design alternatives collaboratively Selection of design alternatives	The set of activity and tasks will encourage social interaction amongst the players to analyse and discuss various alternatives relating to retrofit and/or maintenance.

Table 3: Activities, tasks and purpose of the retrofit and maintenance learning module

6. Implementation of the gaming environment

The D4E 3D on-line gaming environment will be integrated within the web environment and created using a variety of low polygon modelling techniques (3ds Max) to produce assets and texturing techniques (Adobe Photoshop) to add detail without increasing the geometric complexity. This will enable the game to run on various platforms while maintaining quality and frame rate. These assets will then be visualised using the Unreal Engine 4 (UE4). Within UE4, lighting, materials and interactive programming will be added to create the functionality required in the game, to allow users to interactively design their optimal energy efficient environments. Figure 5 represents examples of screenshots of the 3D model of the house that the users will use to explore various solutions to improve its design taking energy performance and cost into consideration.

Figure 5: Examples of screenshots of the 3D house model with solar panels (left) and new cost and energy performance values (right)

7. Conclusion

This paper provided a solid foundation for developing a 3D on-line gaming environment that allows users to learn about various energy solutions and improve their competence in designing better 'Green Buildings'. The 3D on-line tool provides an interactive environment to enable users to explore various 'what-if scenarios' individually as well as collectively in a 'team space' and investigate the impact of their decisions and choices on cost as well as on energy performance.

The design and implementation of the gaming environment was driven by the knowledge captured in the D4E project. For this reason, the learning modules are structured around the three scenarios of new design, neighbourhood and retrofit and maintenance. Furthermore, the content of these learning modules is structured around an energy-efficient model to provide the game users with a holistic view concerning designing 'Green Buildings' including the aspects of environment and climate, energy systems and user behaviour.

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