ROOM – A Web-based Interactive Educational Tool on Building Physics

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ABSTRACT: It is known that one of the causes of the performance gap is a disconnect between the ability of building performance software and those that use it. E-learning tools, if designed properly, could be used to address this by educating or re-educating architects and others about building physics. A review of the literature shows that to be successful, any such tool needs to present a consistent pedagogy, support activity-rich interactions and include a meaningful sensory demonstration. The design of a web-based tool (ROOM), which is being developed for assisting the learning of building physics in environmental design, is then described as an example of how to achieve this. Key to ROOM is that it attempts to provide intuitively the high-level visceral knowledge needed of architects. For example, knowing what a reverberation time of 1.5s sounds like, rather than just being able to calculate a reverberation time using a formula; or knowing that increasing the width of a window to improve the average daylight factor is in general less effective than increasing the widow height.
Keywords: e-learning, building physics, visual demonstration, activity-rich interaction, problem-based learning

INTRODUCTION

The rising concern about sustainable development has led to an increasing demand on architects' ability to produce environmentally conscious and responsive designs. A survey (EDUCATE Project Partners, 2012) on 370 architecture firms in 31 countries indicated that around 55% of the firms require skills in sustainable environmental design when employing architects. Unfortunately the studies by Burke (2009), Hankinson and Breytenbach (2012), and Ireton (2012), showed that many consider education in the architectural discipline and their professional working experience insufficient for them to develop an adequate knowledge and skill set with respect to sustainable environmental design.

Applications of e-learning have proved effective in learning enhancement and knowledge transfer in disciplines including medicine, general engineering (Carlile et al., 1998; Pan et al., 2009), and in civil engineering (Ebner and Holzinger, 2005; Bouchlaghem et al., 2010). However the educational tools available for environmental design are very limited. The ones found (Weng, 2015) do not possess many of the desired features of effective e-learning tools, as discussed in the following section.

To explore the potential of improving architects' literacy on building physics through e-learning, a web-based e-learning tool named ROOM is being developed at the University of Bath. ROOM features highly interactive visual/audio demonstrations designed to encourage conducting problem-based learning (PBL).

This paper reviews the desired features of effective e-learning tools, then provides a description of ROOM.

DESIGN OF EFFECTIVE E-LEARNING

Education is evolving with the implementation of e-learning within various aspects, including storing and accessing of learning materials (e.g. digital libraries), managing learning (e.g. Blackboard), and engaging with knowledge (e.g. visual demonstrations, digital modelling). The selection of technology upon which an e-learning tool is built is crucial for the tool to have the desired result (Brown and Voltz, 2005).

Another feature equally important is that the workflow of such tools should be designed to be consistent with the pedagogy in which the tool is used (Morrison, 2004). Problem-based learning (PBL) is a well-acknowledged pedagogy, which motivates the learner to persuade active learning and encourages the learner to improve their problem-solving skills. A typical way of conducting PBL is tackling a pre-defined problem using the trial-and-error method.

The learner centred active learning process can be effectively guided and sustained with activity-rich interactions (Brown and Voltz, 2005), which requires the e-learning tool to organise user activities under the framework shown on Figure 1. Context describes the general situation based on which abstract concepts and variables can be converted into specific objects that the learner can interact with. For instance the building physics of daylight can be more intuitively explained under a specific room setting (i.e. a window with set dimensions and properties, and internal wall and floor surfaces being of set areas and properties etc.). What-if scenarios (e.g. what if the widow is increased in width by 20%?) can then be examined. This approach should be contrasted with textbook-style learning, where the fundamental equations are taught at the beginning and experiential and experimental learning postponed or sometimes ignored.

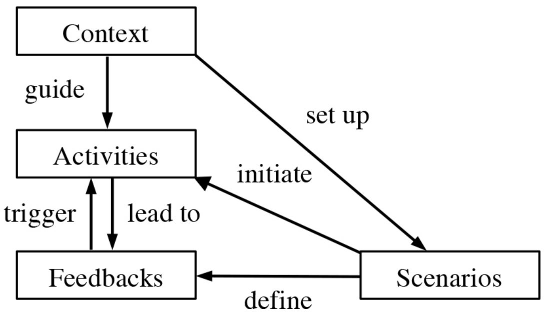


Figure 1: The framework of activity-rich interactions

According to the dual coding theory, information received verbally as well as visually can be recalled and retrieved more easily as it is stored in two different segments of the long-term memory (Rieber, 1994; Braden, 1996). Visualised information is particularly beneficial for architects who essentially learn and work with visual materials. Even before the invention of e-learning, lab demonstration has been used as an enhancement in teaching building physics (Cowan, 1960). The design of visualisation follows the same rule of designing a presentation, i.e. that the contents being presented should be selective and concise, as otherwise it can lead to overloading of information, which distracts the learner from interpreting the visualisation.

ORIGIN AND DEVELOPMENT OF ROOM

ROOM was originally created to visualise basic building physics. It is therefore a modern manifestation of the lab-bench demonstration. The tool is based on a "shoebox" room that contains sufficient elements to serve as a context for the visual/audio demonstration of fundamental building physics about light, air, heat and sound.

The first version was a stand-alone application developed using Processing (McCullen and Basurra, 2013), and has only been used internally at the University of Bath. The new version is being built in web pages to enhance multi-platform versatility. Only an up-to-date web browser is needed and no installation is required. This helps the tool be promoted more easily.

The new ROOM inherited part of the visual demonstrations of the original design, but has been reformed to integrate demonstrations with activity-rich interactions and PBL.

THE USER INTERFACE

As shown on Figure 2, the layout of the interface is simple, with the visual demonstration canvas in the centre, the navigation bar on the top and the panel of inputs on the right.

The visual demonstration responds instantaneously to any user input and the view of the 3D room model can be rotated by dragging (desktop device) or 2-finger tapping (touchscreen device) the canvas.

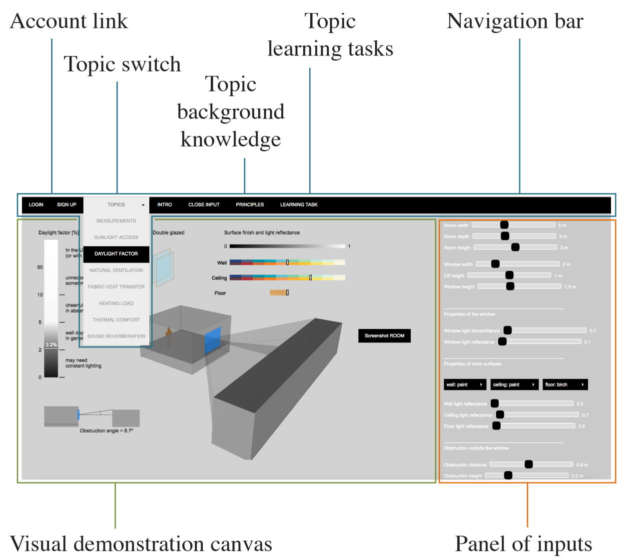


Figure 2: The user interface

ROOM currently covers seven topics, which are: sunlight (solar geometry), daylight access, natural ventilation, fabric heat transfer, heating load approximation, thermal comfort (PMV method), and acoustics (reverberation). Sliders are used for the user to give numerical inputs. Toggles are used for switching between different modes / scenarios (e.g. wind / buoyancy driven ventilation). Other elements for input include dropdown lists, tick boxes and buttons. 'Screenshot' button allows the user to capture and record the visual demonstration canvas.

VISUAL DEMONSTRATIONS

Visualising data within a 3D model is becoming increasingly common in current building design and analysis tools (Integrated Environmental Solutions, 2015;

DesignBuilder Software, 2015). Compared to the simulation tools such as commercial thermal simulation tools, visualisations in ROOM are far more visceral, which makes them more suitable for a learning tool.

Figure 3 shows an example. Apart from displaying the white sun-patch that moves and reshapes as the user changes the position and size of the window or orientation of the building, two other views show simultaneously a section showing the solar altitude and a plan showing the solar azimuth. The latter immediately emphasises that the sun patch would be the same in all locations with similar latitude, thereby providing the user with generalised high-level, not project specific, knowledge. The section and plan views similarly help the user to perceive better the meaning of the solar angles, by presenting together the resultant environmental condition (the sun patch) on the 3D model and a diagrammatic visualisation of inputs (or driving forces).

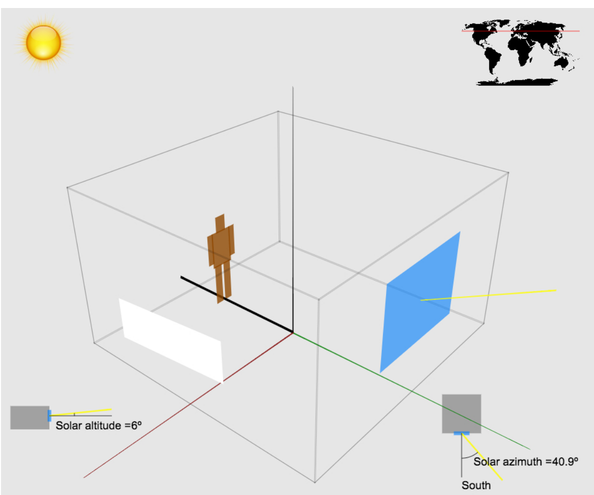
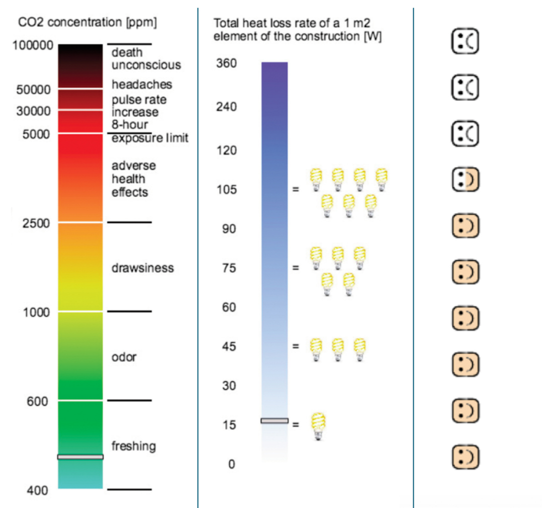


Figure 3: Visualisation of access to sunlight in the room

The meaning of numerical outputs can be difficult to comprehend; especially when no clue is given on how the result is related to any knowledge with which one is familiar. Regarding this, the legends and scales in ROOM, as illustrated in Figure 4 (drawn from three different screens), have been designed to give a preliminary interpretation of the numerical outputs, with translated concepts that are more likely to be familiar to the user. In the left hand column one can get an idea of the air quality in a room compared to the impact of different levels that might exist. The user therefore learns not only what the concentration is in the room, but what levels give rise to various impacts. Again, ensuring general rather than project-specific learning.

The middle column shows the heat loss from the room represented in terms the energy use of an equivalent number of typical CFL bulbs The third legend uses happy/sad faces to better explain PPD (percentage of people dissatisfied).



Display impact of different CO_2 levels to show its relationship with air quality	Display typical CFL light bulbs to provide an intuitive perception of the energy flow rate	Display happy / sad faces to help explain percentage of people dissatisfied

Figure 4: Visualisations on the legend

ACTIVITY-RICH INTERACTIONS AND PROBLEM-BASED LEARNING

The design of the activity-rich interactions in ROOM is shown on Figure 5. It can be seen that the design follows the framework given on Figure 1, and it fully supports problem-based learning.

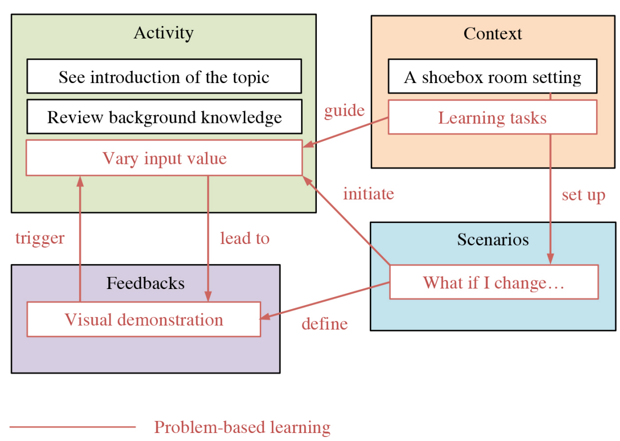


Figure 5: The design of the activity-rich interactions in ROOM

The learning tasks are provided as extra guidance to assist PBL. Each task contains a few what-if scenarios and also gives step-by-step instructions on how to plan the trial-and-error interactions.

ROOM also enables the user to carry out a more advanced type of study: parametric analysis. As shown on Figure 6, after switching on the parametric study mode, one can select the parameters to be involved via the panel of inputs. In this example, curves showing how daylight factor varies with the input parameters are plotted, in combination with the range of possible daylight factors for this room (displayed on the legend). The user can also see the visualisation on the 3D room model simultaneously.

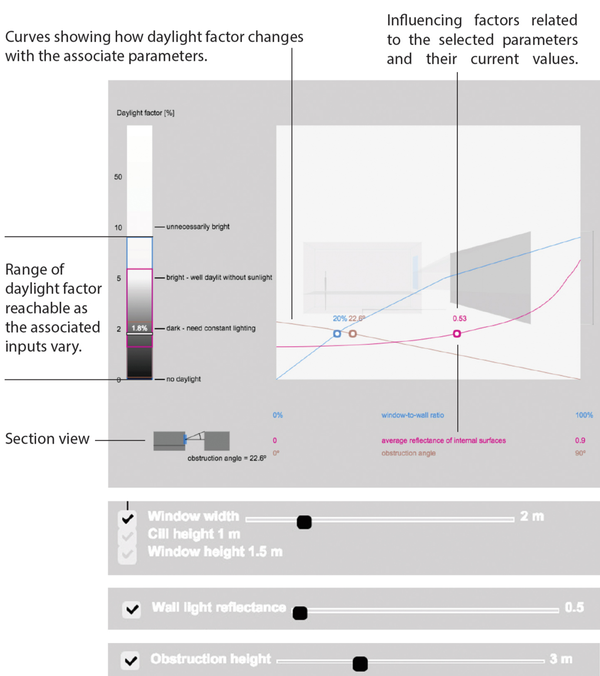


Figure 6: The parametric study mode in the daylight access tab

CONCLUSION

A review of designing effective e-learning tools found that the desired features include:

1. Workflow of the tool being consistent with the pedagogy upon which the tool is based

2. Activity-rich interactions following a 'context-scenario-activity-feedback' framework

3. Visual demonstrations to enhance information transfer, yet being selective in presenting the visualised information

The description of the design of ROOM helps illustrate how to implement the above features in an e-learning tool in environmental design.

It is hoped that this paper successfully introduces the newly developed tool to the academic community and other professionals interested in learning about environmental design.

ROOM can be accessed via the following link: http://people.bath.ac.uk/zw305/ROOM/

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