THE DEVELOPMENT OF A GAME-BASED TEACHING AND LEARNING TOOL TO AID THE SELECTION OF SUSTAINABLE BUILDING MATERIALS

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ABSTRACT

This paper describes the research, development, design, production and testing of a prototype set of playing cards entitled 'Eco-Construction Trumps'. These are intended to be used as a teaching and learning resource within an educational setting and as a source of reference for the built environment professions. They contain data on the sustainability credentials of common building materials and the aim is for the cards to be used to stimulate debate on how, in practice, decision-makers need to balance the differing criteria that are used to establish the environmental impact of construction materials. Research has shown that there is a disparate body of existing knowledge related to the subject matter which until now has not been collated into a single resource. Through interactive workshops, participants' perceptions of using the cards are analysed in relation to game-based learning initiatives.

INTRODUCTION

The design, construction, operation and use of buildings has a significant impact on the natural environment in terms of energy use, the burning of fossil fuels, CO_2 emissions, the depletion of finite resources, air, water and ground pollution, biodiversity and the production of waste.

The built environment in the UK accounts for 50% of all CO_2 emissions amounting to 360 million tonnes of CO_2 released into the atmosphere per year (BRE 2003) and produces 120 million tonnes of waste (WRAP 2007) and studies have shown (Horvath 2004) that up to 29% of all solid waste going to landfill originates from construction and demolition. During the process of decomposition this can result in the release of methane, a greenhouse gas, with four times the global warming potential of CO_2. There is an ever-increasing need for the provision of built environments as the global population is anticipated to exceed 9 billion by 2050 and there is strong scientific consensus that human endeavours, such as construction, will contribute exponentially to global warming with resultant effects on climate change and sea level rises, with potentially disastrous effects for life on earth.

Legislation (Climate Change Act 2008) sets legally binding national greenhouse gas reduction targets of 34% by 2020 and at least 80% by 2050 compared to 1990 levels. There have been a number of initiatives over the past few decades focussed on reducing the environmental impact of the built environment. The recognition that building practices need to change are evidenced by revisions in legislation with targets for zero carbon and low water usage new-build housing by as early as 2016 and new build non-domestic buildings by 2019 for England and Wales (DCLG 2007).

As well as global, national and regional environmental benefits of a more sustainable built environment, there are social advantages in terms of 'healthier' buildings which reduce the risk of sick building syndrome, increasing the health and well-being and optimising the productivity of occupants plus economic benefits by investing now in a more sustainable and secure future, as indicated in the Stern Report (Stern 2006).

ENVIRONMENTAL IMPACT OF BUILDING MATERIALS

420 million tonnes of materials are used in the construction of buildings in the UK each year (Lazarus 2002) which accounts for 30-50% by volume of all manufactured goods, excluding food production (Roaf 2004). 120 million tonnes ends up as waste from construction, demolition refurbishment and excavation processes and it has been estimated that 20 million tonnes of *unused* materials end up in landfill each year (WRAP 2007). Over their entire lifecycle, materials used in construction contribute a significant amount to the environmental impact of the construction sector in terms of the extraction of

finite raw materials, their processing, transportation, manufacture into building products, packaging, installation on-site and their destination after primary use.

In order to reduce the environmental impact of building materials those responsible for creating and maintaining our built environment must engage with sustainable material issues at each stage of procurement, design, construction and beyond the design life of the materials. For example, during the construction phase alone, research has shown that CO_2 emissions can be reduced by as much as 30% through a careful selection of low environmental impact materials (Gonzalez and Navarro 2006).

The issue needs to be addressed across the whole construction cycle from the brief through to construction of the project and beyond the life of the building. This has led to the development of a range of analytical techniques collectively called environmental life-cycle assessment (LCA). There are also number of guides, resources and initiatives aimed at tackling the environmental impact of construction materials, including the Building Research Establishment (BRE) Green Guide to Specification and the Waste & Resources Action Plan (WRAP) 'halving waste to landfill' initiative.

However, research has shown (Greenspec 2010) that there is a quite disparate body of existing data related to the sustainability credentials and environmental impact of construction materials due in part to the complexity of the market with a wide variety of materials and alternatives available, lack of comprehensive research in this field and often unsubstantiated manufacturers' claims. Therefore it is difficult for built environment students and professionals alike to access clear, concise and impartial data without undertaking time-consuming information-gathering and research activities.

GAME-BASED LEARNING

The need to understand and apply sustainable building practices is continually increasing. The ability to absorb technical information can be daunting for built environment students and professionals alike and the value of games, used to support training and learning, has been widely recognised for many years (Coleman, 1971). Lujan and Di Carlo (2005) argue that "the packed curriculum leaves little time for students to acquire a deep understanding of the subject or to develop life-long skills such as critical thinking, problem solving, and communication". It has been shown that lecturing merely exposes students to content, and exposure is not sufficient for learning. Active processing of information, not passive reception of information, leads to learning (Bolles 1988).

An area of neglect is the role and responsibility of educators to make learning fun. This is important because students must become life-time learners, particularly in the ever-changing field of sustainable construction methods, materials and technologies. The use of innovative educational games can increase enthusiasm and reinforce previously presented didactic information (Odenweller et al 1998). Games create a challenging, constructively competitive atmosphere that facilitates interaction among learners in a friendly and fun environment (Lujan and Di Carlo 2005).

Active and experiential learning strategies reach all types of learners in the visual, auditory and tactile learning styles. Research by Fleming (1992) suggests that visual learners have a preference for seeing. Auditory learner's best learn through listening to debates and discussions. Tactile learners prefer to learn via experience; moving, touching, and doing.

The development of 'Eco-Construction Trumps' is an attempt to collate a wide body of sustainability data on construction materials into a single resource in order to assist in the selection of sustainable materials but also to act as an educational catalyst to encourage debate and discussion on a complex topic. Rather than focusing on one material's environmental effects, which may not provide much of an explanation out of context, it is often more valuable to perform a comparative assessment of construction materials. Franklin and Peat (2003) describe the use of such aids to "stimulate group discussion, by bringing together information and concepts from a number of sources to assist learners in the pulling together and linking of material".

In a recent report it has been highlighted that the key challenge for effective learning with games is for the experience to be undertaken in relation to clear learning outcomes as well as being made relevant to real world contexts and practice (De Freitas, 2005).

The success of game-based learning strategies owes to active participation and interaction being at the centre of the experience, and signals that current educational methods are not engaging students enough. Experience with and affinity for games as learning tools is an increasingly universal characteristic among those entering higher education and the workforce. (New Horizon Report 2009)

Accordingly, this project intends to bring the concept of gaming into the classroom of built environment students, who, as experience shows, learn best within applied and action-based settings (Cavanagh 2011)

GAME DEVELOPMENT

The research, development and production of the game-based teaching and learning resource, entitled 'Eco-Construction Trumps', was funded by the Centre for Sustainable Communities Achieved through Integrated Professional Education (C-SCAIPE) based in the School of Surveying and Planning at Kingston University London. The design was an in-house collaboration with a multimedia developer within the Information Services Department at Kingston University. Initially 2,000 packs have been produced by a professional playing card manufacturer to distribute among prospective students at open days and at exhibitions and conferences raising awareness of both sustainability issues in the built environment and the profile of Kingston University London.

The aim is to bring their operation within the learning environment acting as an aid to support the wider built environment curriculum in order to stimulate debate on how, in practice, decision-makers need to balance the differing criteria that are used to establish the environmental impact of construction materials.

The game can be used across disciplines, age groups and educational levels but has been specifically designed for use in an undergraduate built environment setting. The potential beneficiaries will therefore comprise anyone concerned with the environmental impact of building materials such as teachers, students, academics and existing built environment professionals.

The cards focus on 6 key sustainability criteria: embodied energy, embodied carbon, recyclability, landfill decomposition, toxicity and durability of 30 common construction materials bringing together a wide variety of otherwise disparate sets of data into a coherent and accessible teaching, learning and reference resource (see Figure 1) allowing for direct comparison and evaluation through experiential game-based learning.

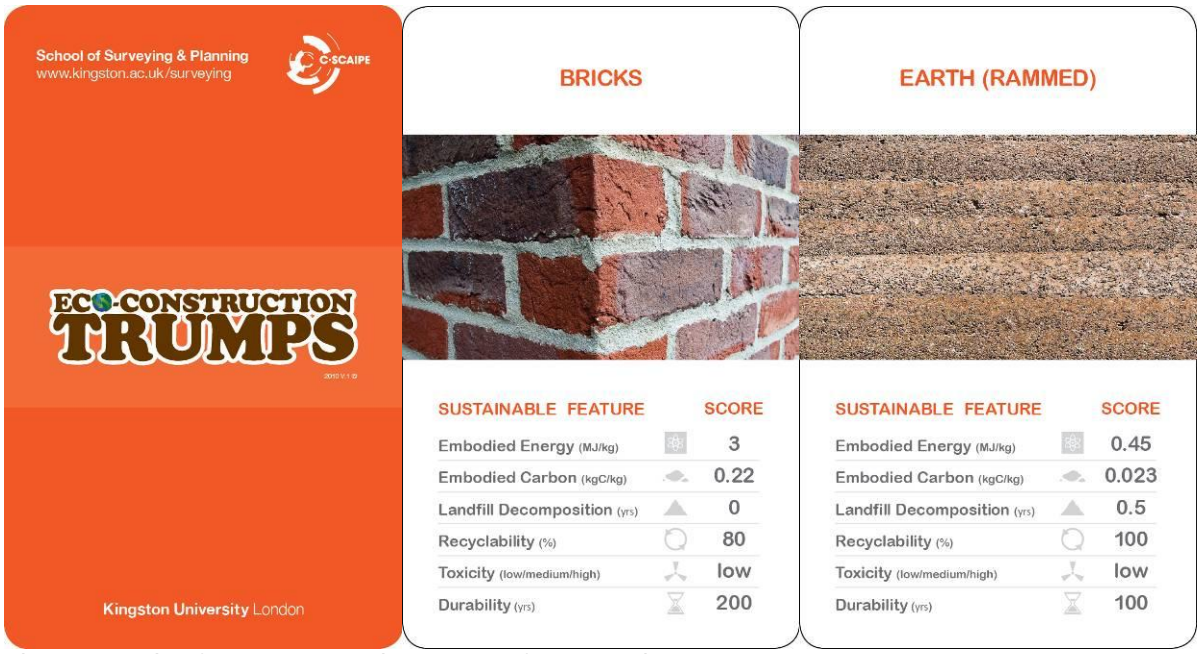

Fig 1 Example of Eco-Construction Trumps format and content.

Included in the pack are instructions on how to play the game and concise definitions of each of the sustainable features against which different construction materials are able to be compared. Each of the categories is described below:

Embodied energy
Measured in mega joules per kilogram, embodied energy takes into account all the energy consumed over a defined lifecycle of a material. In this case from 'cradle-to-gate' which is the extraction of raw materials through manufacture and transportation to site. (Lowest score wins). Longer lifecycles can be considered and discussed such as 'cradle-to-grave' to the end of a materials' useful life and 'cradle-to-cradle' representing the complete cycle beyond end-of-life.

Embodied carbon
Measured in kilograms of carbon per kilogram, embodied carbon also measures all energy consumed during the defined lifecycle, but takes into account the source of the energy and its impact on the environment. (Lowest score wins). Discussion can focus on renewable and non-renewable sources of energy throughout the process.

Recyclability
Recyclability is the capacity of a material to be captured, separated from a waste stream and processed for conversion or reuse. (Highest score wins). Discussion can focus on the selection of composite or mono-materials. Primary mono-materials consist only of themselves as provided by nature e.g. wood, straw and clay. Secondary mono-materials are industrialised but are still homogenous e.g. steel or glass. These can be recycled repeatedly but composite materials can be more difficult to segregate and therefore, recycle.

Landfill decomposition
A landfill site is basically a disposal facility where waste is permanently buried. Different materials decompose, or biodegrade, at different rates (measured in years) and have different environmental impacts depending on their chemical composition. (Lowest score wins). Diverting waste from landfill is key. This encourages other uses for the materials, prevents methane gas production and frees land for more productive uses.

Toxicity
The degree to which a material can harm humans, animals or natural systems. Toxicity can refer to the effect on a whole organism, such as an animal, bacterium or plant, as well as the effect on a substructure of the organism, such as a cell or an organism. (Lowest score wins). Building materials can have toxic effects in their production through industrial processes, in-use contributing to Sick Building Syndrome, impacting on the health and well-being of occupants and also on the natural environment after disposal, causing ground, air and water pollution.

Durability
The number of years the product will last before needing to be replaced. The more durable a material is the better the component performs from a sustainability perspective. (Highest score wins). Generally, long term durability of a building, its components and materials is desirable but can be at odds with the need for adaptability and the need to recycle and reuse elements.

Other criteria were considered, such as recycled content, embodied water and organic content but preliminary research indicated a lack of empirical data at the time, indicating the need for further research in this field. There were also considerably more construction materials that could have been included but design limitations meant only 30 could be selected. This supports the argument for the development of further packs into a series of Eco-Construction Trumps broadening the scope of the cards as a comprehensive design tool and teaching and learning resource.

RESEARCH STUDY METHOD

One of the main barriers to uptake of games in a learning context is the lack of empirical data to support the hypothesis for its effectiveness, as well as a lack of understanding about how these games might be used most appropriately in practice.

The study used a questionnaire to investigate participants' perceptions of the value and importance of the active learning and cooperative activities they undertook during workshops. Three workshops were undertaken with 32 participants in order to elicit both qualitative and quantitative data about perceptions from playing the game. The workshops ran for an hour. The game was played for the first half hour in groups of five or six and for the second half hour the participants were asked to complete a questionnaire with time for discussion afterwards. Two of the workshops were held at 'Ecobuild 2011' (a sustainable construction conference and exhibition) and one workshop was held at The University of Brighton with MA students on the Sustainable Design course.

FINDINGS FROM WORKSHOPS

Fig. 2 A 'word cloud' indicating feedback from workshops wordle.net

The questionnaire elicited a great deal of useful data regarding the perceptions of the respondents to playing the game. Figure 2 shows responses to the question 'what 3 words come to mind when you think of the cards?' represented in a 'word cloud' which gives greater prominence to words that appear more frequently in the source data. Clearly the most popular answer was 'fun' which has been highlighted as a key driver for using game-based learning. The second most popular response was 'informative' again reinforcing previous research findings that learning can occur through game-based initiatives and thirdly 'engaging' indicating that interest was maintained. In descending order of significant frequency came 'interesting', 'play', 'thought-provoking', 'useful', 'materials', 'competition' and 'education'.

When asked 'how did you find playing the game?' 43.7% of the respondents found the game 'very easy' and 56.3% found the game to be 'relatively easy' to play whilst none found the game 'difficult' or 'very difficult'. Additional comments suggested that "it's a good, fun icebreaker to engage people" and initially the participants took a short time to familiarise themselves with the game play "it took a while to get going but then we flew!" As the game was not facilitator-driven self-directed learning was encouraged. Some of the participants found the definitions and concepts a little difficult to grasp but this encouraged discussion and debate based on the definitions on the cards.

In terms of usefulness in their field of work 46.9% found the game 'quite useful', 34.4% found the game 'very useful', 15.6% found it to be 'moderately useful' and 3.1% thought it not to be useful. Many of the participants related the subject matter to elements of course content or directly with work they

were undertaking stating that the game offers the research on these materials in a very accessible and interactive way and that the cards reinforced the success of 'play' in information sharing.

When asked 'how has your understanding of sustainable material selection improved as a result of playing the game?' all respondents indicated some improvement with 6.7% stating their understanding had improved 'completely', 40% 'significantly' and 53.3 %, moderately'. Additional comments included that playing for longer or a few more times would increase understanding. One participant stated that the game helped the understanding of the whole process of evaluating material impact.

In terms of engagement with the game 63.3% were 'very interested' and 36.7% were 'interested' with no respondents stating they were either 'bored' or 'slightly bored'. One respondent stated that "competing always excites people!"

41.4% would 'definitely' recommend the cards to colleagues and 58.6% would be 'likely' to recommend the cards to colleagues.

Other questions related to understanding the data which many stated became clearer after reading the definitions and discussing their meanings during the game. Some of the data was not available which frustrated some players and interrupted the flow of the game whilst some were surprised at materials they had considered to be of high environmental impact that proved to have an overall lower impact e.g. concrete.

There were many suggestions on how the cards could be used in different or innovative ways including as a research resource "it makes finding information really easy instead of trawling through the internet!" and as an educational tool on training courses or to engage members of the public and non-specialists. There were also a number of ideas for developing and expanding the resource to enable comparison of specific materials, for example, a whole set dedicated to insulation materials and related topics such as renewable energy versus non-renewable energy sources, sustainable communities and lifestyle habits.

Criticisms of the cards included the need for clearer definitions and that some of the data was too general. Some participants questioned the validity of the data, illustrating the difficulty of quantifying sustainability criteria from a number of data sets and product champions who wanted their material to be shown in the best environmental light possible, even if in contradiction to some of the research findings. Another criticism was the inability of the cards to be updated and that they could quickly become obsolete in the light of future research and construction material developments. This is a good case for having an online version that could be easily updated and either played remotely online or printed, for use as a physical resource.

CONCLUSION

The need for a more sustainable built environment is widely accepted and construction materials have significant potential throughout their lifecycle to have positive benefits for the environment by reducing our reliance on finite resources, eliminating damaging production processes and long–distance transportation of materials, making it easier to recycle and reuse materials, using materials in a durable way and specifying non-toxic materials with low embodied energy from renewable sources.

Sustainable construction materials also have social and economic benefits in providing healthier indoor environments which encourage greater productivity and profitability through the health and well-being of occupants and ultimately the population, saving on national health expenditure, having more durable and adaptable buildings, designing-out waste avoiding increasingly expensive disposal costs and cutting out costly sourcing of virgin materials.

The range of green building materials and products that are currently available has grown exponentially in response to the growth in awareness of environmental issues and the emergence of sustainable building rating systems. They offer a range of aesthetic options, perform well and are cost-competitive.

Education and raising awareness within the current built environment sector and of future professionals is key to the adoption of sustainable working practices and understanding of the impact

of construction materials. This can often be seen as an extra layer of complexity in what is already a very complex industry. It has been shown that game-based learning has a place in contributing to educational provision where these complex issues can be tackled in a fun, informative and engaging way.

Combining environmental impact criteria into a card game encourages a non-lecturing educational experience and provides an opportunity to engage students, staff and professionals in discussion and creates a source of reference that will assist in sustainable construction material selection.

It is generally thought that students have better retention and understanding of knowledge when taught by active as opposed to passive methods. Therefore, the curriculum must be adjusted to incorporate active methods that provide educational experiences designed to develop life-long learners and students who are capable of solving novel problems and challenges, in short, self-educators. It is hoped that use of the cards will lead to adjustments in some teaching & learning strategies.

It is hoped to develop this concept further for a professional audience allowing for even wider dissemination and potential impact beyond built environment undergraduates and into practice and industry. There is scope for developing a series of cards based on the Eco-Construction Trumps theme expanding on the original set with additional construction materials related to other sustainability criteria. There is also potential for comparison of exemplar sustainable buildings on their sustainability credentials.

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