TOWARDS INTEROPERABILITY: ICT IN ACADEMIC CURRICULA FOR SUSTAINABLE CONSTRUCTION

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Abstract
Sustainability has been regarded as a key issue in both process and product development in industries, e.g., manufacturing, production. The construction industry has recently recognized the importance of sustainable processes in achieving overall sustainability. Demands for cheaper, faster and better products coupled with the globalization of the economic markets are forcing the construction industry to move towards an integrated business process. In order to achieve this integration, information and knowledge sharing are considered vital to reduce waste of resources hence fostering sustainability.

Integration of process and information in a diversified, multi-disciplinary workforce like construction depends mostly on the individual’s level of expertise. Efforts at producing interoperable information standards by a growing number of alliances changing the information flow from horizontal to vertical and from sequential to cyclic. This implies that the actors in the industry must be proficient with the current and emerging Information and Communication Technologies (ICT). Recent surveys show that, there is a widening gap between required ICT skill in the workplace and those taught in academic institutions.

This paper establishes the need for ICT in construction education emphasizing interoperability as a concept among processes to achieve sustainability.

Keywords: Sustainable construction, Interoperability, ICT, Academic curriculum.

1.0 INTRODUCTION
The 21st century has seen a new demand for sustainable constructed facilities (Wenblad, 2000). Despite the building industry fundamentally operating the same way for decades (Bazjanac and Crawley, 1997), customer dissatisfaction, waste, mismanagement, inefficiency, management crises (Saxena and Ally, 1995)(Howard, 2000) and unsustainable project delivery (Arnold, 2000) are some of the many factors that have led to increased pressure for sustainable construction products.

This has resulted in the introduction of a range of systems and software tools aimed at addressing sustainability at various stages so as to facilitate construction business. Examples include environmental management systems (Wenblad, 2000). Demand for sustainable product development has, among other things, increased competition and altered the corporate scenario for construction business worldwide (ibid). Sustainability in construction, as an attitude rather than a topic of instruction, has been identified as another key driver of change in the modus operandi of business in the AEC/FM industry (Egan, 1998).

Sustainability pressure has exacerbated heavy business constraints of time, complexity and operational disintegration (Vadhavkar & Pena Mora, 2000) forcing enterprises, small and large, to incorporate Information and Communication Technologies (ICT) into business processes (Hassan and McCaffer, 2002). ICT technologies are aimed at supporting information sharing among individuals (Hassanain et al, 2000). The Construction industry of today and of the future demand the use of sustainable systems enabled by information and communication technologies.

2.0 SUSTAINABILITY IN CONSTRUCTION
According to the CIB (2002) sustainable construction refers to the social, economic and environmental sustainability of buildings and infrastructure works and the wider built environment and also of the Building and Construction Industry. Meaning to produce constructed facilities that can sustain:

- The ecological environment by protecting the resources as well as the ecosystem;
- The investment (economic) outlay in both the short and long run, including use;
- The social and cultural affairs such as health and comfort, heritage and other cultural values within the location of the facility (Lee and Kua, 2002).

Construction products are currently unsustainable (Howard, 2000) because they consume huge quantities of raw materials and energy, and have the largest environmental impact than any other industry. A more sustainable construction, maintenance and operation of the built environment would largely contribute to sustainable development (CIB, 2002) which means meeting the needs of the present without compromising the ability of future generations to meet their own needs (Toakley and Aroni, 1998). Sustainability in Construction is broad, requiring interdisciplinary and integrated approach (Ibid) as articulated in figure 1.0.

2.1 Changes In The Global AEC/FM Industry
A sustainable built environment requires a paradigm shift in the construction process from linear to cyclic by incorporating life-cycle information into the final product, integrating the processes with a view to reducing on waste. Scholars emphasise availing of knowledge so as to minimise resource consumption, maximise resource use, increase the use of renewable and recyclable sources, protect natural environment and heritage and keep it healthy and non-toxic (Miyatake, 1996, Lee & Kua, 2002, Howard, 2000). Maintenance of high and stable levels of economic growth and employment and social progress that recognises the needs of everyone (DTI, 2001) are other key factors for sustainable construction.

Sustainable construction product development has legal implications, creating greater competitiveness in the construction business. A systems approach to producing constructed facilities as well as changing corporate scenarios, to achieve environmental friendliness, has emerged (Wenblad, 2000). However the perception of sustainability differs from stage to stage and player to player (See figure 1.0 above). The only common need in such an environment is need for information to be shared between different players. Knowledge and information sharing in the building life cycle has existed for decades, using conventional and contemporary information
Figure 1.0: Building Life Cycle vs Sustainability Factors

Generic Building Life Cycle (PMI 1996)

Initial Phases
- Predominantly Design

Intermediate Phases
- Predominantly Construction

Final Phases
- Predominantly Operation

Economics
- Type of work
- Project Size
- Labour
- Structure of the industry
- Business Environment
- Healthy & Safety
- Investment
- Costs & Benefits
- Recycling

Resources
- Land
- Energy
- Transport
- Minerals
- Timber
- Health & Safety
- Construction
- Activity

Building Operation
- Energy use
- Water use
- Sanitation use
- Transport

Pollution
- Gases
- Noise
- Solid waste
- Liquid waste

Social Aspects
- Impact on community
- Decent & Affordable housing
- Security
- Education
- Access to transport
- Others

Others

Predominant Players
- Client & Representatives
- Designers
- Arch. Eng. QS. PM

Predominant Players
- Building Team
- Contractor
- Specialists, Mech. Elec

Predominant Players
- Facility Manager
- Bankers

Information format C

Interoperability Standards
E.g. IFC, STEP, Need for Interoperability

Information format B

Interoperability

Information format A

Interoperability needs a good education in ICT. Even though Interoperability and ICT cannot be a panacea to sustainable construction it would be illogical to rule them out as some of the tangible means of achieving an integrated way of doing construction business.

3.0 FUTURE PROJECTIONS FOR THE AEC/FM

Facility developers and managers still require large amounts of data of various types for quality and efficient management (Wang and Xie, 2002). Information such as management of utilities, maintenance, space, energy, tenant and environmental compliance is available and recorded on standalone computers or control status (Ibid). Interoperability has the ability to link multiple standalone systems, such as building control systems from a variety of manufacturers based on standard protocols (Ibid). The continuing development of the Industry Foundation Classes (IFC) creates new possibilities for achieving interoperability for design software through the use of common object model of the building and its open data transfer standard (Karola et al., 2002). When using the IFC standard, the work of manual data impute required by end users diminishes because data can be imported directly from the IFC file created by other trends (Ibid).
Therefore tends in interoperability may change the construction business strategies, hence affecting sustainability positively or otherwise. Interoperability technologies are still being developed and there is a great need for participation if adequate data exchange standard is to be achieved in the building industry (Augenbroe and Eastman, 2002).

4.0 CHANGING FACE OF THE AEC/FM EDUCATION GLOBALLY

The call for sustainable construction has resulted in the creation of information management systems in construction and demands professional involvement through out the building life cycle (Al-Reshaid and Kartam, 2000). Sustainable product performance and management are key factors affecting ICT education globally. If sustainability is to be achieved, there is a great need for interoperability, which in turn demands education with regard to ICT.

While some schools may have ‘greened’ the curricula by introducing waste management, ecological and environmental courses (Novosa et al, 2002), ICT education has not been embraced with the same enthusiasm and as detailed as it requires. A more multi-faceted approach to achieving sustainability in construction is required (Toakley and Aroni, 1998) incorporating ICT as a fundamental component. Construction sustainability therefore requires adequate investment in people and machines and in the construction process (Howard, 2000).

5.0 CURRENT STATUS OF THE AEC/FM EDUCATION IN DEVELOPING COUNTRIES

Construction in developing countries (DCs) is not immune to global factors affecting industries in developed countries yet it is more fragmented; comprising a regulated formal part where government regulations such as registration are adhered to and unregulated informal part where some or all of the rules are not complied with (Mlinga and Wells, 2002). Infrastructure and educational problems in developing countries pose immediate barriers to becoming global economies and attaining the levels of technological development, which could enhance their global competitiveness (Hipkin and Bennett, 2002). This ha weakened their position (Garmichael and Honor, 2002). In many countries only the small and often insignificant components of their economies are articulated into the integrated world (Soudien 2000). If people in developing countries are unable to acquire the capabilities for using the new ICT applications they will be increasingly disadvantaged or excluded from participating in the global information society (Mansell 1999) (Awake may 22, 2002) (Saxeina and Ally, 1995). Education in ICT can leap frog developing countries’ sustainable construction capability. Information poverty that exists in DCs (Kiiski and Pohjola, 2002) is not an inhibiting factor to lack of the education in ICT per se. Lack of future oriented policies on education (Masini, 2002) is more devastating.

Having identified the pressure sustainability is placing on current and future construction to meet their challenges, and the resultant need of personnel and information this paper sets out to define the tool sets, techniques and actors in fostering ICT education for sustainable construction. A questionnaire is used elicit the data in relation to the use of ICT in the construction industry and an analysis is performed on this data to define the educational requirements for ICT in construction.

6.0 THE SURVEY DESIGN AND ANALYSIS

After considering the time frame, costs and the nature of the topic (ICT), an online questionnaire survey was adopted as the most efficient approach to gathering data for the paper. The survey had three major sections:

1. Personal and institutional details- where relationship between ICT education and geographical location could be inferred;
2. Current status of the ICT in the institution;
3. Opinion for the future.

Below is the questionnaire sequence model, showing the flow of questions and how the relate to each other.

Figure 1.10: Questionnaire Design Sequence Model.

6.10 Sample Size and Population

In order to get as much respondents as we could, with a wide professional, educational and location variety, web-based questionnaire was posted to various research groups such as CNBRI for circulation, with a request for participants in the survey. Thirty-five (35 Nr) respondents sent valid responses, therefore we decided to go ahead with the analysis, since 35 was considered relatively enough for this survey. Respondents fell in to the following categories:

Table 1.00: Category Of Survey Respondents by Profession

<table>
<thead>
<tr>
<th>Category</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction Management</td>
<td>3</td>
</tr>
<tr>
<td>Architecture</td>
<td>10</td>
</tr>
<tr>
<td>Engineering Civil</td>
<td>9</td>
</tr>
<tr>
<td>Engineering Building</td>
<td>2</td>
</tr>
<tr>
<td>Services</td>
<td>4</td>
</tr>
<tr>
<td>Quantity Surveying</td>
<td>4</td>
</tr>
<tr>
<td>Project Management</td>
<td>7</td>
</tr>
<tr>
<td>Others</td>
<td>35</td>
</tr>
</tbody>
</table>

Table 1.10: Category Of Survey Respondents by Positions

<table>
<thead>
<tr>
<th>Category</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecturer</td>
<td>11</td>
</tr>
<tr>
<td>Associate Professor</td>
<td>6</td>
</tr>
<tr>
<td>Professor</td>
<td>4</td>
</tr>
<tr>
<td>Administrator</td>
<td>1</td>
</tr>
<tr>
<td>Others</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td>35</td>
</tr>
</tbody>
</table>
6.2 Analysis

6.2.1 Level of ICT training

Using a scale of one (1N) to four (4N), the level of current ICT training was assessed as shown in table 2.00 below. Scale 01 meant basic knowledge such as word processing, spreadsheets, Internet usage and Web authoring, while 02 meant Intermediate stage, where Computer Aided Design and Drafting and many more such programs are taught; including some basic computer programming.

Scale 03 meant semi-advanced level, where industry based programs are taught, CAD, Primavera being examples. Then 04 meant Advanced level, where Application development and customised applications are taught.

From the table 2.00, it can be observed that Inter-mediate level scores the highest rate from civil engineering respondents while semi-advanced stage is the second highest rated from architectural respondents. However summation of each scale, as indicated on table 2.00 shows that Basic knowledge of ICT has the highest score of 12, followed by Intermediate and semi-advanced stages with scores of ten each. Advanced stage scored 3, meaning the level of ICT training is predominantly basic covering software applications that are generic to most businesses.

6.2.2 Medium of Communication

To assess data exchange within an institution, the medium of communication for class work was requested from respondents. Three possible mediums were suggested; the first being paper, the second was electronic and the third was a hybrid of the two. Table 2.10 below shows the results. Architectural respondents used electronic form of communication more than other respondents while Civil engineering respondents used a hybrid. The summation result shows that paper based communication was far less than electronic form, while hybrid was excessively used than the individual forms. It means paper based communication is till prevalent in learning institutions, though the trend is decreasing.

6.2.3 Industry Concept

With reference to the communication medium selected, construction business concepts are being promoted in the training institutions? The following were suggested: (i) Collaborative Engineering (ii) Visualisation (iii) e-Commerce (iv) Interoperability and (v) Any other.

Table 2.00: Current Level Of ICT Training Worldwide
Responses indicated that individual or a combination of concepts was selected, as presented in Table 2.20 above. The most taught concept was collaborative engineering at 42.8%, seconded by visualisation at 20%. None of the concepts were taught by 17.1% while interoperability and e-Commerce were at 2.8% each. A combination of interoperability and e-Commerce was at 2.8% as well. While integration is being pursued through collaborative engineering, it is evident that interoperability is far from being grasped as an emerging concept in the construction-training arena.

6.2.4 Method of Teaching ICT
The questionnaire suggested three combinations for teaching ICT. The first was stand-alone method, where the course is taught separate from any other application course, such as design studios. The second was part of studio course method, where the ICT course is taught simultaneously with the application course, and the third was a combination of the two. The most used system is stand-alone, Table 2.30 below shows. Stand-alone method, on one hand, is flexible enough to allow specialised personnel to teach ICT for construction even though their construction background may be weak. On the other hand, application of ICT training will depend on the specialisation of the trainer, making it difficult for some professional disciplines.

6.2.5 Teaching Alumni
Exchange of training programs between the industry as well as the training institutions was envisaged by using an alumni method. Because there is an ever-increasing change in the demand of services, training institutions may help the industry or vice versa through continuous training programs. This could be achieved through (i) CPD—continuous professional development (ii) Online short courses (iii) Distance learning (iv) None credit courses and (v) none of the four.

Table 2.30: Method of Teaching ICT

The survey results in Table 2.40 below indicate that online short courses are not offered. Continuous professional development is predominant among professions, meaning the onus is on the graduate to pursue professional development programs run either by the former academic institution or the professional bodies. Other alumni teaching methods suggested by the authors were not in use.

Table 2.40: Teaching Alumni Program

6.2.6 Area of Emphasis
Each respondent was asked to state the area of ICT training they emphasise. The response on chart 2.00 below shows that 25.7% emphasised 3D modeling and visualisation while 24.4% emphasised CAD drafting. Such a result tallies with the sample population of 10 Nr Architectural designers as well as 11 Nr Engineers.

12.9% of the respondents emphasised Design/Engineering computations while numerical analysis stood at 10%. The lowest was CAD management at 5.7% emphasis. Emphasis on project planning stood at 21.4%. Comparatively, all professions covered the area of project planning. It shows how generic and vital project planning tools and techniques are to construction business.

Chart 2.00: Area of Emphasis in ICT Training

6.2.7 Software Used
A list of software used for teaching included Spreadsheets, Word processors, Architectural packages such as AutoCAD, Quantity surveying packages such as win
QS and planning packages such as MS project planner. Others included Energy analysis packages such as Energy plus, programming packages, 3D visual packages and web authoring. From the above-summarised list, it can easily be argued that ICT training in construction is not short of relevant packages. What one cannot tell is the degree to which they are put to use, especially in achieving integrated operations.

6.2.7 Constraints to ICT Education Programs
Three major constraints were reported in the survey. These are financial difficulties (25.6%), lack of infrastructure (23.3%) and lack of trained and experienced academics (20.9%). See Table 2.50 below. 16.3% of the respondents said the ICT education is not considered to be part of the professional degree requirement in their institutions. Such a constraint largely depends on the structure of education systems in respective institutions. Quick succession of software product upgrades (9.3%) and other reasons (4.7%) are not serious impediments to ICT education in the construction industries.

6.3 Future Prospects of ICT Education
To assess the future of the ICT education in the construction industry three main areas were covered. These were (i) rating the importance of ICT on a scale of 1 Nr to 4 (ii) indicating the frequency of upgrading ICT curricula and (iii) the best delivery method.

6.3.1 Importance of ICT for the future
The rating was as follows: 1 meant introducing concepts, 2 meant teaching concepts with industry examples, 3 meant teaching in simulated industrial environment and 4 meant teaching detailed material with industrial apprenticeship. Teaching in simulated industrial environment (3) scored 15 Nr (or 42.9%) while teaching concepts with industry examples (2) scored 12 Nr (or 34.3%). Introducing concepts alone (1) scored 3 Nr (or 8.6%) while teaching detailed material with industry apprenticeship scored 5 Nr (or 14.3%).

Table 2.50: ICT Education Constraints

<table>
<thead>
<tr>
<th>ICT Education Constraints</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick succession of Software Products</td>
<td>10.2%</td>
</tr>
<tr>
<td>Financial</td>
<td>15.3%</td>
</tr>
<tr>
<td>Lack of Infrastructure</td>
<td>12.5%</td>
</tr>
<tr>
<td>Lack of Trained and Experienced academics</td>
<td>4.7%</td>
</tr>
<tr>
<td>Not Part of the degree requirement</td>
<td>14.3%</td>
</tr>
</tbody>
</table>

The results indicate that the perceived importance of ICT in the education curricula calls for teaching with industry examples in simulated industry environments. Too basic or indeed too detailed education (coupled with apprenticeship) is not vital for the future.

6.3.3 Frequency of Upgrading the ICT Curricula
It was envisaged that 80% of the respondents favoured upgrading the ICT curricula every after 2 years. On the other hand 20% suggested upgrading the curricula every after 5 years. This means that the respondents are aware that the field of ICT keeps changing at a very fast rate. To cope with the rapid change of the ICT environment world wide, the curricula must keep changing as well so as to cover areas necessary for education.

6.3.4 The Best Delivery Method
40% of the respondents were for the idea of using web-intranet based delivery system while 37.1% suggested a combination of streaming[video or audio] and web based tools. Virtual reality instruction (at 14.3%) and other methods (at 8.6%) were not favoured for future delivery methods, but they cannot be avoided because they include hands on method, lecture notes, tutorials and laboratory work and interface discussions. This means that while new methods are being researched, existing ones are equally vital.

7.0 THE PROPOSED ICT EDUCATION CURRICULA FOR SUSTAINABLE CONSTRUCTION
Results from this survey act as indicators to the way forward in ICT education. A prescriptive curriculum cannot be achieved because there are other vital factors beyond the scope of the survey that are worth considering. The salient points from the ICT education survey are as follows:

- Upholding collaborative engineering is possible and has lead to integrated approach to construction education;
- Even though both paper and electronic systems of communication are predominant, electronic delivery of information (web-intranet) is to be encouraged;
- Teaching ICT as stand-alone courses is better, so as to allow as much flexibility as possible;
- Continuous professional development maximises the freedom that exists in educational institutions, enabling graduates to learn adaptive techniques, allowing rigid industrial demands can be learnt in the industry using flexible education from academics;
- Interoperability concepts are vital yet they are not used in ICT education;
- As far as is practicable, teach software engineering, information modeling and object oriented software, so as to complement lessons in the AEC/FM market;
- While emphasis should not be on every change that the industry experiences in ICT, revise the curriculum as frequently as every 2 years;
- Include as much simulation and practicals as possible so as to reduce on post graduation training and ease industry integration.

8.0 Conclusion
The demand for a paradigm shift in construction business, created by the pressure for sustainable constructed products, has swept the globe and no doubt brings forth
the over-reliance on information and communication technology for information capturing and sharing amongst players in the building life cycle. The result has been the need to share information of the same format using a similar standard amongst software tools. The interoperability among these tools demands a reasonable education in information modeling, software engineering and object-oriented software. Therefore, a curriculum for sustainable construction would encompass these areas to some degree, over and above the construction market and project delivery education. Technology alone would not bring about sustainability, but it would help in enhancing information sharing.

9.0 References


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