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## Learning for Low Carbon Living: The potential of mobile learning applications for built environment trades and professionals in Australia.

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### Abstract

Professionals and tradespeople do not promote low carbon building options unless they have proven solutions and confidence to implement them. Consequently, without effective education and training they continue to 'lock in' high carbon options. Studies of education and training in sustainable and low-carbon building practices indicate collaborative learning approaches are required to address this issue. This paper presents interim results arguing there is potential to explore mobile learning application opportunities using user segmentation and emotional goal modelling methods. The research challenge addressed by this project is how to equip and motivate professionals, tradespeople and consumers to adopt low carbon opportunities.

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*Keywords:* education; built environment; mobile learning; sustainability; emotional requirements; user segmentation

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### 1. Introduction

Highly experienced and skilled professionals and tradespeople do not promote low carbon or sustainable building options to clients unless they have knowledge of proven solutions and the confidence to implement them [1]. Consequently, without effective education and training built environment (BE) professionals and tradespeople continue to 'lock in' high carbon options, while locking out or limiting the selection and implementation of available low carbon opportunities. Studies of education, training and professional practice [2,3,4] in sustainable and low-carbon building practices also indicate that collaborative learning approaches (and indeed, learning to collaborate)

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are necessary in order to develop the skills and working relationships necessary to optimise sustainability and carbon reduction opportunities in design, engineering, construction and operational phases of a building project.

This interdependency highlights the need for a collaborative approach to raising knowledge and building experiences and confidence to motivate action in the BE. The research challenge addressed by this project, funded by the Cooperative Research Centre for Low-Carbon Living (CRC LCL), is how to equip and motivate professionals, tradespeople and consumers to embrace opportunities by working collaboratively to adopt low carbon products and services. This paper presents interim results from three distinct-but-related PhD studies aiming to identify the opportunities to engage the building and property sectors in education and training for a low carbon built environment and collaboratively contribute to low carbon high performance buildings (HPB). The integrated research approach supports the development and facilitation of a team-based and game-based mobile learning program and is guided by theories related to workplace learning and development [5], end-user modeling [6] and mobile learning [7,8,9,10,11].

## 1. Research Objectives & Context

### 1.1. Australian Built Environment Industry Challenges

The building sector is the third largest economic sector in Australia with total construction activity valued at \$4.45 billion in 2015, producing eight percent of the gross domestic product and directly employing over one million people or nine percent of the Australian workforce while indirectly supporting a large upstream and downstream supply chain [12]. According to the findings from an Australian study [13], the top two global factors influencing the industry over the next 20 years include sensitivity to sustainable development and computer and communication technologies. This and other studies [14,15,16] acknowledge that the BE workforce is fragmented with many challenges associated with inter-organizational practices across a range of disciplines and specializations requiring not only coordination, but also collaboration or co-configuration to enable the fully integrated activities required to achieve HPB. The industry is grappling with a cultural shift in planning, design, architecture (A), engineering (E), construction (C), facilities management and associated work practices. This is mainly due to specialized roles, technology and the increasing complexity of HPB, such as:

1. urbanization, sustainable built environments and reducing greenhouse gas emissions;
2. use of digital technology, in particular mobile devices, building information modeling technology; and
3. integrated design and collaborative construction.

Therefore, these industry challenges need to be effectively addressed in vocational, higher education and continuing professional development (CPD).

## 2. Literature Review

At the project onset, literature reviews were conducted to identify the methods of learning, technology use, and the availability of information and programs for vocational trade apprentices and BE practitioners promoting sustainability, energy efficiency, carbon reduction and zero carbon buildings. This was in addition to literature on research methods and theories associated with workplace learning and development [5] and mobile learning [7,8,9,10,11] to investigate the options for new learning programs.

### 2.1. Knowledge management and practitioner engagement

Recent Australian studies [15,16] focusing on knowledge management and engagement of building professionals and trades identified that they have little to no engagement in CPD on sustainability, energy efficiency and low carbon strategies. The motivating factors for participating in CPD are improving professional standing and

minimizing commercial risks and the impediments far exceed the incentives [16]. The impediments to widespread adoption of sustainable building practices in Australia include:

- Environmental performance requirements in buildings are not taken seriously: lack of effective environmental performance policy enforcing a sign-off culture where there is little incentive to learn how to implement strategies because there is little risk of being caught for non-compliance.
- Sustainability is perceived as a specialization, typically only for Green Building Council of Australia Green Star Projects or bespoke housing [15]: practitioners do not engage in sustainability knowledge, skills and experience as common practice although compliance is required with the energy efficiency measures in National Construction Code (NCC) and the National Australian Built Environment Rating System (NABERS).
- Engagement is voluntary and market based: Beyond certifier and assessor programs associated with NABERS, there are minimal if any legislative or professional requirements for practitioners and no trade requirements for engagement in CPD linked to sustainability, energy efficiency or carbon reduction strategies on an ongoing basis [16, p. 5], although a plethora of voluntary programs are available.
- Education and training materials are unappealing: building practitioners identified the language used in educational and training materials is either too abstract or the information provided is overly complex and too difficult for most to understand [15].

To address these issues, CPD programs must be designed to include basic sustainability, a foundational understanding of energy efficiency concepts, critical thinking and be contextualized in work-flow related activities as situated learning while engaged in the job at hand. Phase I of the National Energy Efficiency Building Project [15] identified “the key problem is not the lack of availability of quality information or training but that what is available does not offer practical application to implementation - the ‘how to’ information, education and training – that can readily be integrated into daily work tasks [15, p.114].”

## 2.2. Collaboration

Workplace learning and development offers practitioners an opportunity to engage in situated and contextualized training linked to work practices. Three comparative studies [17,18,19] on collaboration, integration and co-configuration offer insight into workplace learning and development. The first study by Kocaturk [17] aims to understand the differences in collaborative and individual creation of knowledge, concluding that non-linear processes of knowledge creation in digital design environments have initiated the creation of shared meaning between members of the design team. Kocaturk’s argues this contradicts the product oriented view of knowledge in favour of a process oriented view of knowledge, which is key to understanding the emerging collaborative knowledge [17, p. 54]. His view of ‘distributed cognition’ aims to “move the discussion away from one single discipline or individual to a group of multidisciplinary individuals situated within the context of complex environments [17, p. 55].” In addition, the second study [18] uses an intervention method to analyse and transform work and learning in three organisations while investigating forms of co-configuration focusing on the development of products and services that adapt to the changing needs of users. And the third study [19] describes the various levels of integration required and sets out the twelve characteristics of an integrated team, which are being considered as part of the current study.

## 2.3. Mediating Technology

The technological tools required to achieve high performing buildings include computers, mobile devices, hand-held electronics and wearable technology. These technologies play a significant role in designing, engineering and building while using the Internet, software (e.g. computational assessment and analysis), communication and documentation to mediate BE industry practices and outcomes between clients, professionals and practitioners [17,19,20,21,22,23]. Although the building industry is aware of the need to prepare for the future in light of the

technological revolution, study findings [17] indicate this sector is one of the last to fully embrace technology in comparison to other similar large scale engineering industries, such as automobile manufacturing and aerospace. Weippert and Kajewski argue that over the last forty years, the construction sector has been slow to embrace innovative Information and Communication Technology (ICT) tools and systems, remaining stubbornly resistant to computing technologies and has not adopted lasting change in work processes [23]. They indicate this is not due to the technology, but rather a lack of innovation on the part of the user and more consideration should be aimed at the users' engagement in developing new and improved business practices. The adoption of 3D modelling of design and engineering has never the less gained momentum, and is increasingly aimed at enhancing models throughout the construction and operational phases of projects. Technologies in the form of virtual, augmented and simulated environments and distributed objects offer the potential "...to support buildability, viability, efficiency, sustainable development, whole of life cycle evaluations to inform and improve solutions [17, pp. xxix-xxxii]"

### *2.3.1. Mobile Devices & Learning*

Advances in smartphone technology and the introduction of the tablet have catalysed a dramatic increase in the sales and use of these mobile devices for education and a decrease in the sales and use of desktop computers [24]. Eighty percent of all Australians own a Smartphone, which accounts for 15 million people, and 59 percent of Australian households have access to a tablet [24]. Australians look at their smartphones an average of 30 times a day, while 50 percent of mobile phone users aged between 18-24 check their devices within five minutes of waking in the morning [24]. In fact, there is also a growing body of evidence [6, 7] supporting the use of mobile devices as a mode of learning. Mobile learning involves the use of a Wi-Fi and/or 3/4G enabled devices, Apps and a digital keyboard such as a Smartphone (iPhone, iPod Touch, or android equivalent) or a tablet (iPad or Android equivalent). Recent studies indicate that learners value the 'anytime, anywhere' characteristics of mobile learning, and the ability to communicate and collaborate easily with others. Mobile learning has the potential to facilitate learner created content, opportunities for collaborative learning and provide social connectedness and personalised learning anywhere or anytime. Mobile learning accessed at the point and time of need, helps to contextualise the learning with its application and provide the learner with an opportunity to interact with the environment. Given this ubiquity, what is the potential of mobile learning platforms to prepare and motivate professionals and tradespeople to influence consumers and thereby drive the adoption of carbon efficient products and services?

### *2.4. Users emotional goal modeling*

Mobile app users are affected by a wide range of influences in both engaging and using a software system based on their needs, values and emotions. Human emotions shape users' attitudes and behavior toward a software system such as willingness to accept using a software system or not. Gogueny indicates most of the requirement engineering difficulties are social, political, and cultural and not technical as the requirements in the minds of clients are not always accurate [25].

In requirements engineering literature it is widely argued that soft issues such as users' values and emotions heavily influence requirements engineering process, but there are few discussions on how to deal with these issues. Because of the difficulty in considering users' emotional requirements and lack of systematic way of identifying emotional issues, many studies have emphasized the importance of designing a method to capture such information and using it in an elicitation process to increase the quality of requirements engineering [6,25].

Ramos and Berry investigated the role of fears in some stakeholders when a software system supposed to store information about mistakes and who was responsible for them to show the role of emotional requirements [26]. Krumbholz et. al. argued that there is a direct relation between the negative emotions with users' rejection for using a software system [27]. Colomo-Palacios et al. argue that knowing the stakeholders' emotions helps to understand the reliability and stability of the definition of those requirements [28]. In other study, a method called 'affect grid' is to understand the effect of some emotional requirements based on information elicited [29].

### 2.5. Summary

In summary, the literature indicates there are significant impediments to building practitioners' engagement in CPD. Further, there is an abundance of information available, however the delivery is ineffective in the current form. Collaboration is a key contributor to the development of HPBs leading to increasing demand for practitioners to engage in collaborate work practices and networking opportunities to stay up to date with emerging knowledge, products and practices. In addition, there is increasing usage of mediating technologies in work practices with mobile devices being the most widely used technology. These key findings will inform the next stages of the project to develop a collaborative approach using mobile learning technology to improve practitioners' knowledge and develop experiences to increase action in the BE toward higher performing buildings.

## 3. Proposed Mobile App Design Method

The design of learning apps must encourage, motivate and bring value to potential users. Therefore, it is important to first engage with a sample group of users to identify what and how they 'feel' about the content and using mobile technology and apps, and then design an app to motivate and bring value to all potential users. For this reason, a new method is proposed to identify target users and their emotional needs and requirements based on the general and goal-based criteria. General criteria are widely known variable classification schemes used to separate users into categories using criteria (i.e. geographic, demographic and socio-economic). Such goal-based criteria are dependent on the potential users' functions and thus requires exploration of the prospective users' emotional needs and requirements, including their attitudes toward HPB and the use of mobile technology. The preliminary findings aligned to trade apprentices are explored below.

### 3.1. Selecting Target Users

Deriving requirements that satisfy the needs and desires of users is crucial in designing a mobile learning app. However, to be able to specify these requirements, potential users must be identified and prioritized.. The process of requirement engineering has been used to address these issues and plays an important role in the success of the app development [30,31,32,33]. While there has been research and application into the area of identifying users and their profiles, much of this has been to support traditional apps such as business or defense, rather than in the social domain such as mobile learning apps. These types of social apps offer little in the way of structure because people often do not share the same requirements [34]. For these reasons, in designing the mobile app in this study, it is important to segment and prioritize specific target users among prospective users. This approach is helpful when specific target groups need to be identified and motivated under limited time and budget constraints, as an incremental development strategy. To this effect, the core ideas of market segmentation are adapted into requirements engineering to identify and prioritize the users.

Users are segmented based on the characteristics the criteria identified. This method enables user segmentation based on the general goal-based criteria. In this method, the researchers first analyze the objectives required to build the app. Then analyze the prospective users and categorize them into segments — internally homogeneous and externally heterogeneous groups — based on their needs, relevant characteristics, behavioral tendencies, lifestyles, preferences and what they would like to feel by using the application. Finally, these segments are prioritized against the objectives to select the high-priority segments as target users.

### 3.2. Considering Target Users' Emotional Requirements

Software developers often focus on solutions that are convenient, failing to concentrate on the needs of users to provide an interface that engages them. In fact, most mobile apps are designed with little understanding of users' emotional requirements, ignoring the well-accepted theory that a person's acceptance of a product or service is more influenced by emotion than cognition. Based on Gestalt Theory, people do not perceive a thing as a set of individual features but as a unified whole and in relationship with features [35]. Accordingly, to increase the chance of app adoption and sustainable use by target users, the researchers must consider the influence the app has on the users' emotional perception of the app. From a system design perspective, it is possible to consider emotional requirements

separately as list of atomic requirements; and all of the target user's requirements must be considered as a unified whole or as a holistic perspective. Further, target users may not be aware of the benefits, values and return on investment that a mobile learning app can bring in the short or longer term [36]. This issue surfaces because users don't have specific objectives and therefore are not obliged to use the app. It is therefore critical for the app be designed and developed to motivate, engage and provide knowledge and skills to collaborate on sustainable environments. It is also essential for the researchers to address some of the limitations of current vocational and CPD programs on sustainable construction described in the next section.

To elicit and model the target users' emotional requirements, the researchers propose a technique called *Emotional-Qualitative and Functional Analysis Systematic Technique* (EQ-FAST), an extension of the well-known FAST approach. Using this proposed app development method, the researchers are targeting two specific groups: trade apprentices and BE professionals to model the mobile learning programs based on the qualitative data collected. These two groups influence consumer and client purchasing behavior and therefore have the potential to reduce per-capita carbon consumption.

#### 4. Target Group Summary Findings

In the early stage of the project, preliminary data was collected from a BE industry based focus group using qualitative methods. As a result of the discussions, an in-depth exploratory study of built environment professional culture was designed, as well as further investigation into trades apprentices. A series of one-on-one interviews with lead vocational trade educators were conducted, including plumbing, carpentry, electrical and landscaping trades and building professionals. The preliminary results are summarised in the following sections.

##### 4.1. Focus Group

At the project onset, to engage practitioners in a dialogue to shape the development of a mobile learning program, the team held an industry based focus group [37]. The focus group was conducted over three hours with representatives from commercial and residential design and construction companies, a building product manufacturing company, a building regulatory authority, academic research institutions, national vocational education policy advisory and management agency, and a key building industry association [37]. The discussions were used to elicit information about the use of mobile devices in the industry sector and to identify the key target audiences requiring knowledge and skills development to motivate action and break the cycle of 'locking in' high carbon options, while locking out or limiting the implementation of the available low carbon opportunities.

The focus group identified four types of practitioners: 1) the committed 2) the responders or those who try to do it because their clients demand it, but often fall short 3) the opportunists or those who don't have the know-how, but tell you anything to close the deal and often are unable to deliver; and 4) the avoiders who don't have the know-how and are risk averse to trying new technology, materials, or methods and simply refuse to deliver. A mismatch of practitioners and clients was considered typical, being either a) practitioners with experience in high-performance buildings and clients who do not want one or b) clients who want a HPB with practitioners that do not know how to deliver one. It was considered atypical for a practitioner with experience in the development of HPB to be paired with a client who desires one. Trust was also a contributing factor due to the informants' perceptions a large portion of companies and practitioners in the marketplace green wash or oversell the benefits of HPB, but are typically unable to deliver the anticipated product [37].

For the purposes of this research, the informants identified two key areas requiring further investigation, the engagement methods for building professionals and trades to contribute to HPB and an understanding of the challenges and advantages of using mobile technology and devices in work practices. Due to the degrees of complexity of HPB and project teams, the focus group informants indicated a representative group of architecture, engineering and construction professionals needs to be further engaged to identify collaborative learning opportunities. The group identified other influential roles in the property sector as real estate agents, valuers, mortgage insurance providers and financial lenders, recommending further investigation on their contributions to a high performance BE [37].

#### 4.2. High performance buildings

The focus group identified the advantages of consumers who experience a HPB by stating that they actually feel the benefits [37]. They also noted the advantages of using a thermal imaging camera as a visualisation tool to communication about hot and cold spots in a building. The informants identified the drivers and benefits of engaging in HPB, being:

- Social conscience, peer group interests, activities and attitudes
- Regulations, tender requirements, or industry standards
- Company leadership from the top down in both commercial and residential markets
- Market demand (clients and customers) and energy prices
- Industry awards (competition)
- Higher staff retention rates in commercial office spaces due to the high replacement costs associated with staff turnover.

Although one informant indicated that it's not about being a leader necessarily, but avoiding being the 'others' who are not engaged in practice and are eventually unable to compete in the market. Lastly, all the informants indicated that the residential market would benefit from houses being evaluated and labeled similar to the appliance (energy and water) and car (fuel) labeling schemes of in Australia.

#### 4.3. Continuing Professional Development

The focus group [37] indicated that continuous up skilling, networking and formal CPD are considered essential to keep up to date with changes to regulations, standards, materials and methods. However, the group also highlighted the factors impeding engagement, particularly the time commitment and the associated costs. One major drawback to being a Green Star accredited professional with the Green Building Council of Australia is the requirement of collecting fifteen CPD points per annum to stay certified. However, the advantage of being a Green Star Accredited offered professionals the opportunity to compete in the commercial market and bid for jobs and to network at industry events. Practitioners noted the alternatives to formal engagement as talking to mates on the jobsite or the office, with emphasis on the perception that trades prefer to learn on the job instead of a classroom. They also indicated that practitioners often learn informally mainly by sourcing information from the Internet.

#### 4.4. Mobile Devices

The focus group informants identified the advantages and challenges associated with using mobile devices, including smart phones, tablets and iPads, to support their work practices. Advantages included: the pervasive usage of mobile devices at all levels by pre-vocational apprentices, trades, AEC, and clients. Complementary technologies increase the advantages of mobile devices improving efficiencies in documentation, communication, visualisation and tracking of products, materials, information, site safety and employee inductions. Additional tools also include cameras, global positioning systems (GPS), quick response codes (QR code), audio recording, Bluetooth and even social media to engage with other practitioners, clients and the general public on products, projects and service provision. Internal software and communication mediums are also used, such as drawing programs, measuring, estimating, job tracking, rating programs, file sharing, file storage, and cloud computing.

Drawbacks include the site conditions, size, reliability, preference for paper-based documentation and the social expectations associated with conducting business face to face.

### 5. Summary Findings: Interviews

Interviews [38] were conducted with three vocational trade teachers and a senior level trade education representative (over 30-45 minutes each). The aim of the interviews was to broadly gather data on the preferred

types of mobile device(s) and examples of usage in various contexts (communicating, sourcing information, collaborating, learning, creating and playing). The other focus was on ascertaining in-depth information about using mobile devices for learning and seeking to understand each participant's and their trade students' knowledge and awareness of sustainability in the specific trade areas.

### *5.1. Sustainability and Formal Training*

The study found that there is significant resolve from trade teachers to increase sustainability awareness and behaviors in ways that students also see relevance to their learning and vocation. However, they cited that culture, resources and the relevance of the current sustainability pedagogy to trade teaching and learning as significant impediments to increasing student engagement. Teachers interviewed outlined the existing education programs and the carbon reduction strategies in which they would like trade apprentices to engage. They identified a number of competencies and a standalone unit aimed at methods of work practice to minimise material usage and energy reduction strategies. One such unit for electricians is incorporated into 38 certificate level programs from Certificate I through to Certificate IV [39]. The interviewees noted that students engage more often in sustainable practices when the approaches are incorporated into practical trade learning such as recycling metal, reusing timber or in response to consumer demand for increased efficiency based on offering insight into the types of products that will save on the running costs. The biggest obstacle is disengagement in the stand-alone sustainability unit given that sustainability training is considered most effective when embedded in a relevant and accessible way.

### *5.2. Mobile Devices*

Among trade teachers interviewed, mobile devices were seen as the preferred option for communicating, collaboration and sourcing information due to the nature of the work. Interviewees were asked to identify the types of tasks that they use their mobile devices to complete. In order of frequency, trade teachers identified communication as the most frequent task on their mobile device followed by sourcing information, collaboration and learning with personal and work emails ranking higher than phone calls and text messages. Tradespeople also use app functionality on mobile devices for tasks such as cable selection for electricians or building regulation and compliance and for recording information using camera or video functions.

When asked what technology based tools they would like to see introduced, the tablet was seen as the tool of choice for learning. Therefore, further questions were aimed at gaining an understanding of how the target groups might learn using mobile devices, including the preferred types of content delivery mediums. In order of preference, trade teachers prefer collaboration & coordination with staff & students, then video, audio, and lastly text based content. In terms of content trade teacher's source learning broadly through a variety of formal learning (vocational education, university or school), and informally, like reading (iBooks, Google Scholar, Newspapers, Blogs etc.) and audio podcasts. There was evidence that trade students are more engaged with mobile devices than with computers. One interviewee indicated they support the use of mobile technology as a tool for learning within the trade disciplines covering plumbing, carpentry, building, electrical and landscaping. As users, the motivators for learning on a mobile device were convenience, time and flexibility.

A recent study contradicts these findings, however, indicating that learning and teaching staff are often challenged and lack confidence with having to learn new ways of teaching, new learning pedagogies such as flipping the classroom, collaborative learning techniques, peer to peer assessments and mobile learning when faced with institutional wide change [40].

## **6. Summary & Conclusion**

At this stage, the research findings indicate:

- Sustainable low carbon buildings are perceived as a niche specialisation by BE practitioners; however new entrants to the industry like trade apprentices are engaging with sustainability and energy efficiency as a requirement of occupational



and professional training when integrated into their work practices.

- The professionals and trades in the existing industry have a low level of engagement in formal methods of professional development and even lower levels of engagement in sustainable low carbon building professional development, unless the program is underpinned by compliance with regulations or professional standing, such as GBCA Green Star.
- Trade teachers and apprentices are engaged in learning about sustainability, energy efficiency and carbon mitigation. This group is highly likely to use mobile learning apps to support training if it is successfully integrated into their work practices.
- Mobile devices are an essential technological tool in the building industry, however little is known about how they are used, particularly how they are used to facilitate learning or collaboration related to choosing or recommending sustainable low carbon options.
- It is not known what opportunities are available as workplace development intervention strategies for informal, situated and collaborative learning for trades and professionals in the BE industry.
- Consumers or project owners have been identified as a key audience to engage. The aim is to increase the demand and secure opportunities for sustainable low carbon buildings, thereby increasing the demand for knowledgeable and skilled trades and professionals to contribute.

The interim findings presented in this paper will direct the next stage of the research, based on in-depth explorations of the learning opportunities for trade apprentices and BE professionals. In addition to the preliminary findings related to trade apprentices, an in-depth exploratory study of built environment professional culture has already commenced. Once the further data is collected, the proposed Emotional-Qualitative and Functional Analysis Systematic Technique (EQ-FAST) method will be used to model the mobile learning programs based on the target user groups. Further stages will focus on the efficacy of initial and continued engagement in a mobile learning app to support the uptake of sustainable low carbon opportunities in the building and property sectors in Australia.

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