Energy Awareness Displays: designing a prototype for personalised energy consumption feedback at the workplace

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***Abstract*—The paper describes work-in-progress on a prototype providing personalised energy consumption feedback at the workplace. Based on a provisional framework developed in the context of an ongoing research project the prototype and the supporting infrastructure are conceptually outlined.**

Keywords-ambient learning displays; ubiquitous learning support; conceptual infrastructure; energy conservation; energy awareness displays.

I. INTRODUCTION

Modern office buildings are usually equipped with building automation systems that provide among others central energy management and monitoring services. Data from such systems is often gathered through proprietary software and made available only to a selected audience of engineers or facility managers. Typically, the level of detail of the gathered data does not go beyond a breakdown for the whole building, floor, or department. The main idea behind the presented *Energy Awareness Displays* is to make this data and thus the information that is hidden deep within the office building's infrastructure visible and accessible for the people working in the building - right up to a personal level of detail. In doing so the displays set up to change first and foremost the energy consumption behaviour as well as the attitudes towards energy conservation of employees working in these buildings.

Thereby the overall goal is to raise employee's awareness on the topic, introduce relevant conservation strategies, and provide dynamic situated feedback when taking actions. The underlying assumption is that the raised awareness on the actual consumption fosters a change in behaviour among employees and thus leads to reduced total energy consumption for the employing organisation. The idea is to reach that goal by the means of so-called eco-visualizations, a novel approach to display (real-time) consumption data [1]. On the long-term this visual, situated, real-time feedback on electricity consumption and respective conservation opportunities should facilitate environmental learning and behavioural change.

II. BACKGROUND

The presented prototype is part of a research project focusing on the situated support of informal and non-formal learning scenarios in ubiquitous learning environments by enabling learners to view, access, and interact with contextualized digital content presented in an ambient way. The project explores the characteristics of ubiquitous learning and deduces informational, interactional, and instructional aspects to focus on. The project sets up to establish awareness for relevant information; examine the personal, social, and environmental sense-making process; and evaluate the situated support on its effectiveness for authentic learning. Analysing the theoretical foundations and following an experimental design approach, the project will deliver scientific insights into the authentic learning support in informal and non-formal learning situations and provide suggestions for the future design of ambient systems for learning.

A. Provisional Framework

In order to measure the effects of ambient information systems on learning a provisional framework that acquires, channels, and delivers the information framed in the learning process has been proposed [2]. **Fig. 1** illustrates the framework resulting in what has been defined by the authors as *Ambient Learning Displays* [3].

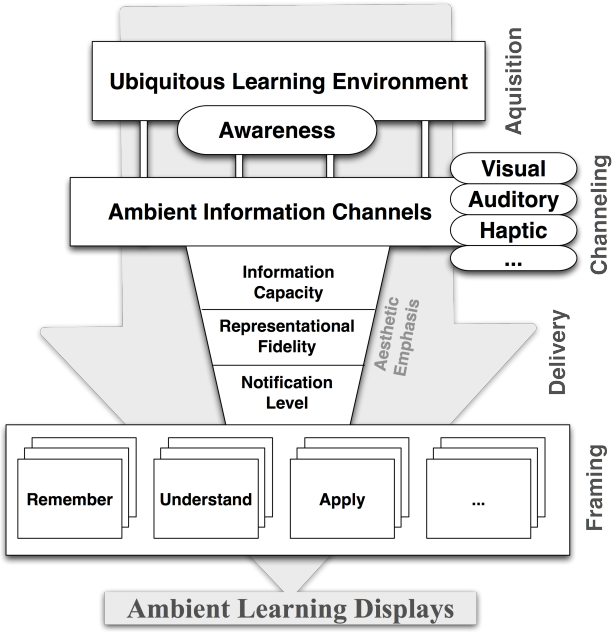

Fig. 1 - Provisional conceptual framework for ambient learning displays [2]

The framework considers informational, interactional, and instructional aspects of ubiquitous learning, derived from its main characteristics [4]. Thereby the informational aspect approaches the support and assistance of ubiquitous learning by enriching the experience with contextualised content and information. The interactional aspect then builds upon this conceptual idea focusing on novel interaction approaches that can facilitate the learning support. Finally the instructional aspect incorporates authentic and situated learning theories focusing on the knowledge construction within corresponding (supported) environments.

B. *Design dimensions*

To deliver the previously channelled information within the ubiquitous learning environment ambient systems are used. Based on the comparison and discussion of existing ambient information systems by [5], the four design dimensions: information capacity, notification level, representational fidelity, and aesthetic emphasis define the design of ambient systems as means of delivery. According to the authors information capacity is determined by the amount of information represented by the system, notification level is the degree of user interruption, representational fidelity describes how the data is encoded, and the last dimension reflects the emphasis put on aesthetics.

III. Energy Awareness Displays

Based on the introduced provisional framework an infrastructure that supports *Energy Awareness Displays* in office buildings will be developed providing the following functionality in relation to the respective framework aspect.

A. *Acquisition & Channelling*

The framework described in the previous section is set up with the acquisition of information relevant to the learner within the ubiquitous learning environment. In the context of the targeted application domain this information is acquired from two main sources. First of all the available energy consumption information offered by existing building automation systems and services is used. Depending on the level of granularity this information allows making a point about the organisational consumption, e.g. the consumption and conservation achievements of a particular building or department. In addition to that the information is used to relate the individual consumption to a greater (organisational) context. To establish this relationship individual energy consumption information is included. Again different levels of granularity are available, i.e. the information can be acquired device specific or as a combination of devices depicting the personal consumption at the workplace as a whole. Also a separation of the consumption information into a work-related and a personal share could be implemented. Technically the individual consumption information is acquired utilising an existing energy monitoring solution [6]. **Fig. 2** illustrates the functional principle built up by a wireless mesh network of smart meter plugs.

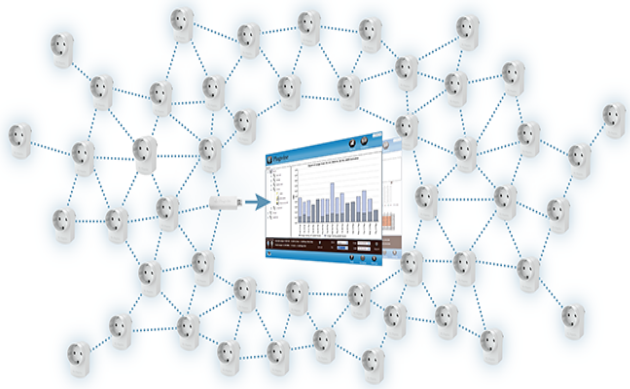

Fig. 2 - Plugwise smart meter plugs network [6]

In combination with the information provided by the existing building automation system the aggregated information extends and enriches the building's overall energy consumption picture. Thus the aggregated information is not only used to acquire and deliver (real-time) energy consumption information, but also to sensor and log data to measure the effectiveness in terms of energy conservation and enable the experimental evaluation. To ease the information channelling as well as the logging procedure a dedicated open data web services for managing real-time sensor data is utilised [7].

B. *Delivery & Framing*

Based on the supporting infrastructure emerging from the acquired and channelled information relevant to the learner the described framework carries on with the delivery and presentation of this information in context. Thereby the following requirements are taken into account.

The information should be publicly available, representing the overall and individual energy consumption in several levels of detail. These levels include personal as well as organisational consumption information. Furthermore the information presentation should allow an explorative comparison of the consumption information in relation to fellow employees, departments, floors, and/or buildings. Again this comparison allows relating the individual consumption to a greater (organisational) context.

Technically the delivery of information is implemented utilising applications that address mainly visual displays. Nevertheless all types of displays, including auditory or haptic displays could be supported by the infrastructure as well. The applications are developed using the Adobe Flash Platform [8] and their development environments. Based on the open-source Flex SDK 4.5.1 the environment supports the development of mobile, web, and desktop applications. Conceptually the applications are based upon the Robotlegs framework [9], supporting the implementation of a Model-View-Controller Service (MVC+S) architecture facilitating the Dependency Injection (DI) design pattern. Following this approach the information can be accessed and explored online or with existing organisational or personal devices, including desktop computers, tablets, and smartphones.

The framing of the previously acquired, channelled, and delivered information in a learning context then complements the described framework. Based on the revised taxonomy of educational objectives [10] activities and objectives enabled by the systems are matched to the types of knowledge and the cognition processes involved. In the context of the targeted application domain aspects, such as motivating and persuading conservation facilitation patterns play an important role. Based on the presented information such measures might include competitive incentives or game elements.

IV. Experimental Evaluation

For an experimental evaluation the prototype needs to fulfil a number of requirements derived on the one hand from the described framework and the given design dimensions and on the other hand from the chosen application context. The main aspect to be considered is the display's ability to deliver the desired information just in time. Thereby the display should be positioned in the periphery of attention, while still being able to move between the periphery and the focus of attention. Based on these requirements the main focus is set on the notification level and the representational fidelity dimension affecting the design of the display prototype and the timed delivery of the presented information.

The effectiveness of the deployed measures on the actual energy consumption of the office building will be measured using the existing building automation system that already provides real-time consumption data complemented by the introduced individual consumption measures. The gathered data can also be compared to buildings identical in construction but without the deployed measures.

As part of the design cycle the developed display prototypes and used visualisation techniques will be evaluated in user-studies to reveal which are most effective in communicating energy consumption data and motivating energy conservation. Furthermore surveys will be conducted to assess whether dynamic visual feedback and the provided facilitation patterns can promote the conservation of electricity at the workplace and measure the increased awareness on the topic as well as changed attitudes and/or changes in behaviour. Additionally the user acceptance and interest will be measured using novel methodologies and techniques, such as experience sampling, mobile eye tracking, and activity sensing.

V. Conclusion

The paper outlines design considerations and development ideas for a prototype providing personalised energy consumption feedback at the workplace. The ideas are based on a provisional framework developed in the context of an ongoing research project. Future work will focus on the implementation and experimental evaluation of the prototype.

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References

[1] T. G. Holmes, "Eco-visualization," in Proceedings of the 6th ACM SIGCHI conference on Creativity & cognition - C&C '07, 2007, pp. 153-162.

[2] D. Börner, M. Kalz, and M. Specht, "A Conceptual Framework for Ambient Learning Displays," in Joint Proceedings of the Work-in-Progress Poster and Invited Young Researcher Symposium for the 18th International Conference on Computers in Education, 2010, pp. 4-6.

[3] D. Börner, M. Kalz, and M. Specht, "Thinking outside the box – A vision on ambient learning displays," International Journal of Technology Enhanced Learning, Special Issue on Ground-breaking Ideas in TEL, submitted.

[4] H. Ogata and Y. Yano, "Context-aware support for computer-supported ubiquitous learning," The 2nd IEEE International Workshop on Wireless and Mobile Technologies in Education, 2004. Proceedings. IEEE, pp. 27-34, 2004.

[5] Z. Pousman and J. Stasko, "A taxonomy of ambient information systems: four patterns of design," in Proceedings of the working conference on Advanced visual interfaces, 2006, pp. 67–74.

[6] Plugwise, "Smart wireless solutions for energy saving, energy monitoring and switching", [http://www.plugwise.com/].

[7] Pachube, "Real-Time Open Data Web Service for the Internet of Things", [https://pachube.com/].

[8] Adobe Flash Platform, "Deliver rich apps and content across screens and devices", [http://www.adobe.com/flashplatform/].

[9] Robotlegs, "ActionScript 3.0 Micro-Architecture Framework", [http://www.robotlegs.org/].

[10] L. W. Anderson and D. R. Krathwohl, Eds., A taxonomy for learning, teaching and assessing: A revision of Bloom's Taxonomy of educational objectives, Complete e. New York, New York, USA: Longman, 2001.

[11] OpenScout Project, "Skill based scouting of open user-generated and community-improved content for management education and training", [http://www.openscout.net/].

[12] STELLAR Project, "Sustaining Technology Enhanced Learning at a LARge scale", [http://stellarnet.eu].

[13] SURFnet, "ICT-based innovation in higher education and research in the Netherlands", [http://www.surfnet.nl/en/].