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An eLearning approach for improving household water efficiency

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Abstract

The increase of available data on household water consumption is expected to bring a new awareness of household water practices. Such awareness needs to be further supported by customized advice to the household. This paper presents the development of a Moodle-based eLearning platform that aims to support end-users to understand, manage and hopefully change their water and energy consumption profile. The paper presents the structure and components of the platform, including, inter alia, FAQ's, quizzes and tips whereas more focus is given on the two most advanced web application for the exploration of domestic water demand profile. The course structure is further informed by a qualitative survey on customers' cognition on the use of web services.

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Keywords: Smart metering; online application; online education; water efficiency; water demand management; Moodle platform; e-learning

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1. Introduction

Recently the deployment of ICT services and smart applications for the monitoring of water and energy consumption at domestic level opens new horizons for sustainable resources management engaging actively customer side ([1], [2]). However, the sterile presentation of high-resolution data or even the very detailed feedback without the direct communication of simple and meaningful messages consist a key barrier for the adoption and frequent use of new technologies ([3], [4]). In this framework, it is essential for end-users to be further supported

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through complementary tools and applications that bring new awareness on household level, bridging, at the same time, the gap between customers and new technological achievements. This paper presents an innovative Moodle-based web service, termed the *eLearning platform*, that comprises a series of smart facilities and applications targeting household end-user. The platform aims to provide householders with knowledge on water-related issues and technologies, enabling them to better understand, manage and hopefully alter the water consumption profile of their household without posing restrictions on their quality of life.

2. The eLearning platform

2.1. Methodology and tools

The eLearning platform is mostly developed around the *Moodle* online suite that consists a virtual learning environment for community based educational processes [5]. Moodle stands for Modular Object-Oriented Dynamic Learning Environment and is an open source web application designed for producing Internet-based educational courses and training programs. It contains essential tools like discussion forums, quizzes, wikis, dictionaries and file sharing, while its key strength derives from its modular nature that enables extensions and integrations by creating plugins for specific new functionalities and web applications, such as those developed in our work. One of those extensions concerns the development of an online what-if modelling application for the simulation of household water network. The *Water Planner* application relies on the *UWOT model* ([6], [7], [8]) that is a conceptual urban water model for the generation, aggregation and transmission of a demand signal, starting from the household water appliances and moving towards the source. This approach provides the flexibility to define any urban water cycle network including conventional water supply or water recycling schemes, combined or separate wastewater systems, one household type or multiple household types, etc. The stand-alone UWOT engine was developed using C whereas the GUI was developed using Python 2.7 and PyQt 4.8 and enables user to define the network topology, the components of the network as well as the connections between these components.

2.2. Qualitative survey on customers' cognition

The course structure as well as the platform's front-end were further supported by an qualitative survey on consumers' cognitions (including perceptions, attitudes, representations, ideas, attributions and emotional and imaginary material) regarding the potential use of web educational applications and ICT technologies on domestic water sector [9]. The research was conducted in the wider area of Athens and consisted of 19 semi-structured individual interviews from consumers, covering a wide range of different socio-demographic characteristics: sex, age, region, household characteristics (number of people living in the house, single, with a partner, family, with or without dependent children), property characteristics (flat, house, with or without balconies, gardens, type of sewer system) and basic socio-economic profile (full time work, part time work, retired, unemployed). The main focus of analysis was to organize the content of provided feedback by coding the desirable ways to exhibit information. The interviews revealed important insights on what information should be provided and how the form of visual presentation should be in order to achieve the optimum knowledge transferability. Regarding the first aspect, participants nominate the possibility to gain educational and functional information in the form of tips (about water and energy consumption, reduction of water and energy bill, environmental care), interactive material (quizzes, games, serious games, FAQ's, competitions within a network to other users) and educational narratively and/or visually water stories on ways of saving water in gardening, agriculture, indoor and outdoor cleaning and car washing. On the other hand, the analysis showed that themes regarding the mean as well as the visual appearance are closely associated with age. Younger ages were proved more flexible with the use of new technologies, while participants over 50 prefer mail by post and information within the water bill. Additionally, the consumers preferred graphics, comprehensive tables and figures, relevant videos and animations, images and sketches of appliances and their water use function as well as short easy messages than extended narratives text.

2.3. The structure and facilities of the eLearning platform

The eLearning platform is built around an interactive and multistage educational process which is evolved and implemented according to a stable knowledge cycle (Fig. 1). Each stage comprises several activities and facilities, serving the different steps of learning approach. Some of them were built upon standard Moodle tools (e.g. FAQ's, quizzes, dictionary etc.) after proper customization and population with relevant material, whereas external systems (e.g. UWOT) were also used for more advanced applications such as those presented in next chapter. The educational process begins with a preparatory stage ("Learning") in which the users receive useful feedback and information about "water identity" with special focus on urban setting. The information is presented through a series of *questions-answers* that cover a wide range of issues related to water at global, urban and finally domestic level. The process continues through a self-assessment stage ("Understanding") that enables users on the one hand to evaluate their consumption behaviours via *quizzes* and on the other hand to discover the current consumption profile of their household. The *Water Calculator – Water Sense*, as it is described in detail in next chapter, presents not only on the bigger picture of water consumption but also details on the breakdown into various indoor and outdoor domestic uses. After improving users' cognition on water issues, the platform supports end-users to explore ways through which they could alter their wasteful behaviours and improve the water efficiency of their household ("Acting stage"). The interactive visual application "*Smart Water Home*" provides cost-effective everyday tips and practices towards the reduction of water demand. The pool of tips covers the majority of possible indoor and outdoor water activities while the virtual navigation into the various places of the houses makes the experience more entertaining and interactive. Further to general practices, the *Water Planner* on-line tool simulates the water cycle of the household, presenting the possible benefits from the adoption of advanced demand management infrastructures and low-consumption appliances ("Evaluating stage"). The web application is fully customised to the household special characteristics and profile and is presented in detail in next chapter. Finally, the platform aims to bring householders closer to the available state-of-the-art ICT tools and services, providing information on their key aspects. In the same framework, *success stories* from the implementation of ICT technologies at global level as well as information on ongoing and past European funded research are also presented ("One Step further" stage). The eLearning platform is a living environment that supports the active participation of the users and the direct communication of ideas through discussion forums and a pool of relevant links and resources ("Additional Guidance" stage).

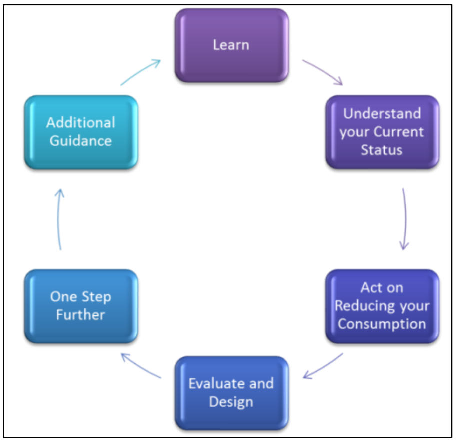


Fig. 1: The knowledge cycle of the eLearning platform

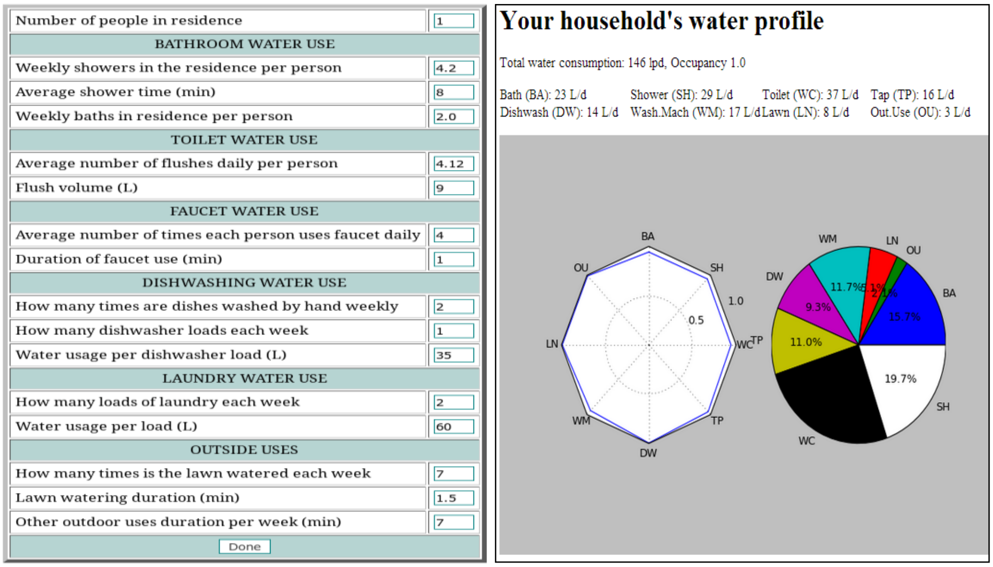
2.4. Facilities and applications of eLearning platform

Among the various facilities of eLearning platform, in this chapter we focus on the two most advanced web applications related to the understating and alteration of the domestic water demand profile. The development was based on external systems and models which via appropriate system integration techniques became part of the main front-end.

(1) The Water Calculator - Water Sense application is a fully customised tool that enables the exploration of the consumption profile of the household, i.e. the average daily water consumption as well as their breakdown into different uses and activities as a percentage of the total amount. As input parameters, the application receives specific information about property characteristics and daily habits (Fig. 2a). The daily water consumption of the different water appliances, in liters per day, is estimated as follows, where italics are the user-defined parameters:

1. $\text{Bath} = 80\ \text{L/use} \times \mathit{Weekly\_baths\_in\_residence\_per\_person}/7 \times \mathit{occupancy}$
2. $\text{Shower} = 6\ \text{L/min} \times \mathit{Average\_shower\_time} \times \mathit{Weekly\_showers\_per\_person}/7 \times \mathit{occupancy}$
3. $\text{Toilet} = \mathit{Average\_number\_of\_daily\_flushes\_per\_person} \times \mathit{Flush\_volume} \times \mathit{occupancy}$
4. $\text{Faucet} = 4\ \text{L/min} \times \mathit{Average\_daily\_uses\_per\_person} \times \mathit{Average\_use\_duration} \times \mathit{occupancy}$
5. $\text{Dishwasher} = 30\ \text{L/use} \times \mathit{Times\_washed\_by\_hand\_weekly}/7 + \mathit{Dishwasher\_loads\_per\_week}/7 \times \mathit{Water\_usage\_per\_load\_}$
6. $\text{Laundry} = \mathit{Loads\_of\_laundry\_per\_week}/7 \times \mathit{Water\_usage\_per\_load\_}(\text{L})$
7. $\text{Lawn} = 5\ \text{L/min} \times \mathit{Lawn\_watering\_per\_week}/7 \times \mathit{Watering\_duration\_}(\text{min})$
8. $\text{Outdoor} = 3\ \text{L/min} \times \mathit{Outdoor\_uses\_duration\_}(\text{min/week})/7$

The results of these calculations are displayed along with average household values corresponding to typical use of water [10], via a spider graph as presented in Fig. 2b. Values greater to 1 correspond to consumption greater than the average whereas values smaller than 1 correspond to consumption lower than the average. Additionally, the breakdown of total daily consumption to various water uses is displayed in the form of a pie chart.



Number of people in residence	1
BATHROOM WATER USE	
Weekly showers in the residence per person	4.2
Average shower time (min)	8
Weekly baths in residence per person	2.0
TOILET WATER USE	
Average number of flushes daily per person	4.12
Flush volume (L)	9
FAUCET WATER USE	
Average number of times each person uses faucet daily	4
Duration of faucet use (min)	1
DISHWASHING WATER USE	
How many times are dishes washed by hand weekly	2
How many dishwasher loads each week	1
Water usage per dishwasher load (L)	35
LAUNDRY WATER USE	
How many loads of laundry each week	2
Water usage per load (L)	60
OUTSIDE USES	
How many times is the lawn watered each week	7
Lawn watering duration (min)	1.5
Other outdoor uses duration per week (min)	7

Your household's water profile

Total water consumption: 146 lpd, Occupancy 1.0

Bath (BA): 23 L/d
Shower (SH): 29 L/d
Toilet (WC): 37 L/d
Tap (TP): 16 L/d
Dishwash (DW): 14 L/d
Wash.Mach (WM): 17 L/d
Lawn (LN): 8 L/d
Out.Use (OU): 3 L/d

a) b)

Fig. 2: a) Household water details required by Water Calculator; b) Results of Water Calculator

(2) The Water Planner is a what-if online modelling tool that can simulate the use of low-consumption appliances and advanced demand management infrastructures. The tool relies on the UWOT model for the simulation of the household water network and operates under three different household setups: (a) a baseline without any water recycling schemes, (b) a configuration with only rainwater harvesting system and (c) a configuration with both rainwater harvesting and greywater recycling. Unlike the available conventional online calculators, *Water Planner* takes into account the climatic conditions of the area (the user can select between Oceanic, Mediterranean, or Desert climatic conditions). Climatic conditions, strongly influence the evapotranspiration and potential garden irrigation needs, as well as, importantly change the estimation of the contribution of the rainwater harvesting system to the households overall water demand reduction. Occupancy, roof area, garden area if available and pervious areas are defined by the user, while in the case of rainwater harvesting and greywater recycling the capacity of the local tank and the treatment unit are also user-defined parameters. The user can also choose between conventional water appliances and Best Available Technologies Not Entailing Excessive Costs (BATNEEC) that can operate in all three settings, hence creating 6 possible household infrastructure scenarios per climatic zone.

For each configuration, suitably customized by user input as discussed, the *Water Planner* presents the simulation results in the form of time series charts that display the daily energy consumption in household water appliances, the runoff volume, the water infiltrating in pervious areas and garden as well as the potable water demand for one year period. In the case of the rainwater and greywater systems, the system also calculates and displays two nomograms of the dependence of potable demand on the local tank capacity and on the percentage of green roof to total roof area. Fig. 3, presents indicative results of simulation with conventional appliances and Oceanic climatic conditions, without water demand management technologies. The consumed energy in the water appliances is constant, the runoff volume and the water infiltration follow the rainfall pattern whereas potable water demand increases during summer because of garden watering.

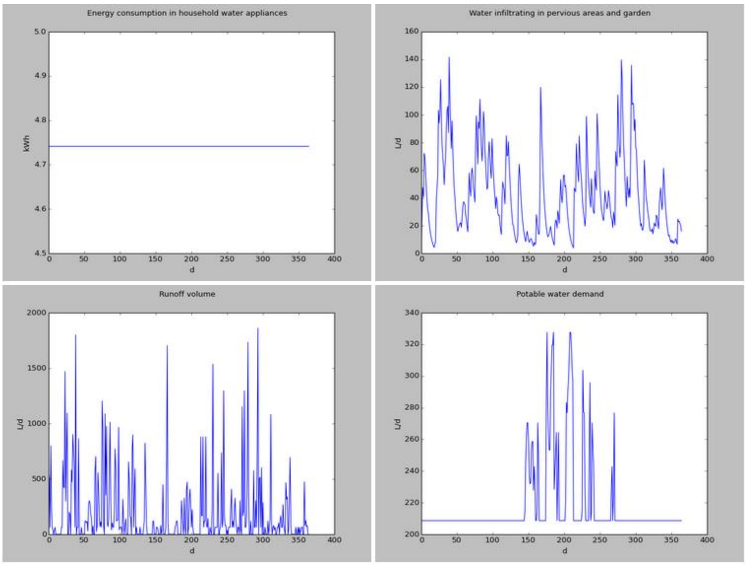


Fig. 3: Results of simulation without water recycling schemes as they derived from Water Planner

Fig. 4 below, presents results of a simulation for a hypothetical household that includes a rainwater harvesting system. Results illustrate significant reductions in potable water demand that can be, for example, achieved, using a typical 1000 L tank. At the same time, the total runoff volume from the roof, garden and pervious areas of the household (excluding garden) also decreases, while a small energy increase can be observed due to the operation of the rainwater harvesting system.

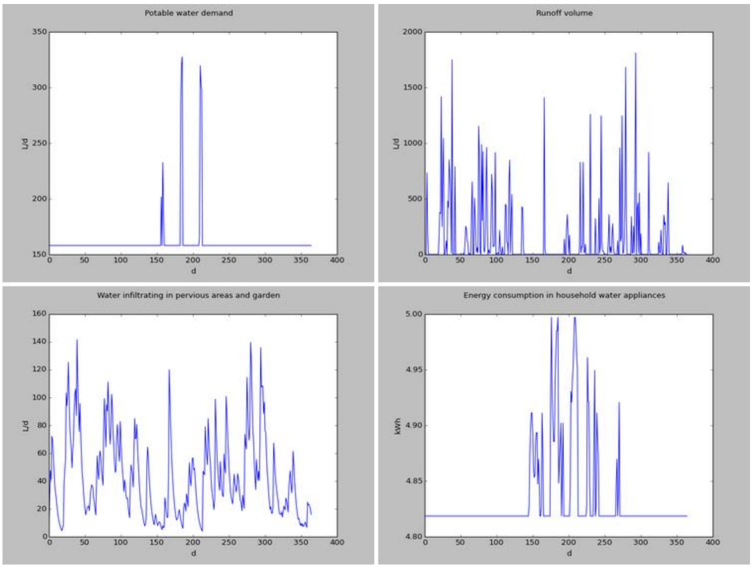


Fig. 4: Results of simulation with rainwater harvesting setup as they derived from Water Planner

3. Conclusions and next steps

This paper presented a series of on-line tools and applications that aim to bring new awareness and increase end-users' cognitions on household water practices. The various facilities were developed around a Moodle on-line platform, following a stable but flexible multistage educational process that meets the necessities and characteristics of a variety of different audiences. In this framework, the eLearning platform aims to support end-users to learn, understand, manage and hopefully improve the water and energy consumption profile of their households via web applications that vary from simple FAQ's and quizzes to more advanced water calculators and what-if modelling tools. The Water Calculator – Water Sense application allows the exploration of the consumption profile of the household, while at the same time, the Water Planner tool enables the simulation of low-consumption appliances and advanced demand management infrastructures presenting information about their water saving potentialities.

The structure and visual display of the course was further supported by a qualitative survey that examined and identified various influential factors associated with customers' attitude towards smart web applications and services. The analysis provided useful input on the content of presented information and its level of detail, informing at the same time the design of the platform's front-end. The survey revealed that end-users prefer visual and direct presentation of information rather than extended and detailed narrative texts.

It is expected that smart web services such as this e-Learning platform will bring a new awareness of household water practices, positioning end-users closer to the center of discussion for an efficient water demand management. At the same time, such initiatives enhance, consolidate and promote the role of on-going developments on smart ICT services for the consumer domain. In this framework, the educational process operates complementary to knowledge extraction from smart water meters, providing the household with both knowledge of their current water profile and quantified options to improve water use at the household level.

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