Advanced Sustainable Home Water Management through Gamification and Mobile Application

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Introduction

The world at large, United States and the state of California (CA) in particular, have all realized that climate change is here and now. The consequences of climate change as declared and asserted by the International Panel of Climate Change range from average temperature rise in the local climates and many other impacts including change in the rain and storm cycles [1]. The State of California has been in drought cycle for some three years now with water storage levels across the state at alarmingly low levels – down by 51.8% [2, 3]. Los Angeles and San Diego (two largest cities of California) have instituted water conservation methods and rebates for all their customers including single family homes. The total amount of water consumed by residential population (as opposed to agriculture or industrial) is about 14 % of the total water consumption in CA (agriculture uses 80%) [4].

Two key programs in the School of Engineering and Computing at our university are - Sustainability Management (MS) and Computer Science (BS and MS). Sustainability Management program focuses on teaching sustainability development per the modern definition encompassing Environment, Economics and Equity (or generally referred to as 3 Es). The Computer Science programs focus on teaching the latest computing models, methods (including mobile Apps) and cyber security. Both departments work together on research projects. This research will be one such combined project.

Federal, state and local governments all have initiated some water conservation programs. Although there are some signs of success in some of these programs, majority of the public and especially local governments have long ways to go before majority of the publics will be totally on board and to have a program with continued success. Public awareness and education of the water scarcity issue is at the heart of the issue, starting with single family water conservation or a Home Water Management Plan (HWM) that is easy to learn, follow and implement, with the ultimate goal of making a mobile application (or App) available to the masses.

This research introduces the awareness and educational aspects of water conservation to our future leaders through 'gamification' (learning through games) at the graduate level Sustainability Management courses, and proposes a plan to bring a HWM mobile app to the masses through local governments, such as city or county. The mobile app approach would be accomplished through a research relationship with the Computer Science department to prototype the gamification (website and mobile app). The ultimate goal for this research and methodology is to take to water supply authorities – interface with city or county water authorities to test and deploy the application for their single family home customers.

Background

The drought caused by lack of rain or precipitation deficit in CA has been well documented [6]. These cities have instituted a water conservation program with incentives for residential and commercial water users [7, 8]. For single family residences, the rebates go across all aspects of water conservation (or elimination in some cases) – from changes faucets to removing turf/lawn.

Given the above drought situation, the CA governor issued an Executive Order [9] to re-double state drought actions and called for a 20% reduction in water usage. These actions along with the reality on the ground demonstrates the immediate need for water conservation (or elimination, as applicable). Although the residential water usage is about 14% of the water usage in CA – it still is an important factor since the total residential water usage by no means is an insignificant amount affecting all the population.

Generally city residents do not have easy access to or aware of how water usage is distributed in residences, particularly in single family residences. Public awareness on water conservation is expected to increase with television advertisements, freeway signs and pamphlets in the monthly utility water bills. These media access still falls short of giving the residents a clear picture of their water usage and its distribution. Further, specific actions are not well laid out or communicated. Pamphlets coming along with water bills are generally thrown away without the customer generally reading them to take any action. There needs to be better ways to bring information to the public and to make them take actions based on facts that is quick, progressively adopted and attractive, based on technology.

We live in a cellular wireless information age today and its impact on society is only beginning, and will continue to bourgeon our current and future societies. We all know the impact of social media on the old and the young in today's life, especially when it comes to the use of mobile apps in smart phones and tablets. Cities and other civic institutions are only beginning to jump on this bandwagon to promote and deploy their services. It is not uncommon to find more than one smart phone in majority of residences in the US. One of the most common and effective apps have been gaming apps on the smart phones. Our work presented here takes advantage of both - the media and the gaming approach to teach students, and to the home owners about HWM.

The objective of the research paper is not only to clearly identify a single family home water usage and its distribution - based on the latest published CA and Environmental Protection Agency (EPA) data – but to go beyond to propose a game app for smart phones for single family HWM. The game app will use realistic residential water usage distribution data and suggest strategies and specific action(s) that a player can take to save water (scarce resource) and thus money (economics) resulting in better environment and equity for all concerned. Players will try different strategies and see the action(s) that suits their situation best. In addition, the app will also show other *sustainable development* benefits – like energy saved (in kWh) and carbon di oxide abatement (for better environment) and other equity benefits (the 3 Es). This information is of utmost importance to educate the public, increase their awareness and for the residents to be responsible citizens by actively participating in water conservation. The researchers strongly believe an informed citizen will be a responsible citizen and the enabler here is technology that is ubiquitous and is easily adaptable.

Use of gamification in teaching and a mobile game App approach makes it fun for all ages without having to remember or recall plenty of data required to calculate the several items related to water savings. The proposal is to have a default set of data (per EPA guidelines) and still give the option to the player to make it more specific to the city (or region).

Data on Residential Water Usage and Its Distribution

The residential consumption and the end use distribution will be discussed here to help quantify the water use in CA and in the United States (US). Quantification and comparison with the rest of the world will also be discussed to understand our use of water. Understanding the water usage and its distribution data is important for the game to help educate the students and home owner. Both CA and EPA data on single family water usage and distribution will be discussed below.

As noted earlier, in CA the 14% of the total water for residential use amounts to about 3.865 billion gals/day and the average per capita usage per person per day is 181 gallons [10]. In 2011, the California Department of Water Resources completed a study on Single family Water Use [11]. The study found some very interesting variation in single family water usage in the two regions of CA – southern and northern Sothern region single family homes use 77% higher amount of water per day.

The main reason for the huge differences can be attributed to the fact the southern CA is a more an arid environment. As such, majority of the water in the southern region in a single family home is for outdoor landscape usage – it is about 185% as compared to the indoor use. For the northern area, outdoor use is lower than in the indoor use (73%). It is also clear from Figure 1 that the indoor use is about the same for both regions. So the southern region cities of CA should be paying high priority for water conservation for their outdoor usage.

Figure 1 below shows how the indoor water usage in a single family home is distributed (recall that both regions use about the same amount of water for indoors.

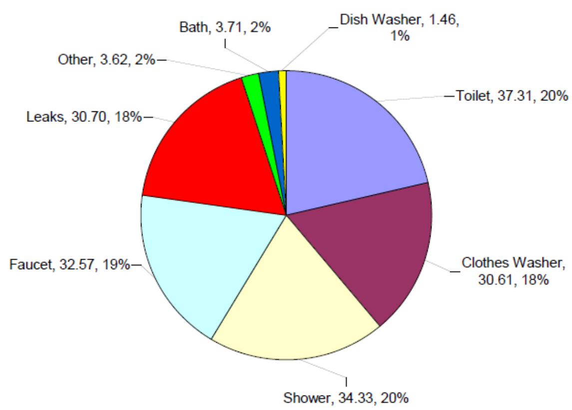

Figure 1 – CA Indoor Water Usage distribution

Similar statistics are available from EPA for a single family American home: per EPA an average American single family residence (family of 4) consumes 400 gallons a day and 70% of that water (280 gallons) is used indoors and 30% (120 gallons) used outdoors [12]. EPA also gives data on how the end use water is distributed, as shown in Figure 2 below.

Figure 2 – US Indoor water distribution per EPA

As would be expected, the water end use distribution percentages are different in some areas between the two sets of data. But interestingly the CA average between the two regions is 409 gallons per day – very close to the EPA number. For the purpose of this research paper, the EPA numbers will be used for all calculations of water savings depending on the action taken so it is applicable to the whole country. These will be further discussed in detail in the gamification section below.

Case for Water Conservation and Public Education

We saw the case for water conservation due to the drought conditions. There is another global reason for water conservation due to the projected population increase. According to an UN report – Water Facts and Trends [12], the per capita use of water per day is shown in Figure 3 below for different countries (developed and others). It is important to note that US per capita consumption is the largest – about three times compared to France (a developed economy) and about seven times compared to China (a developing economy).

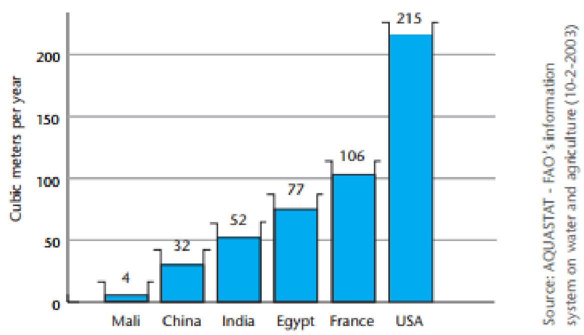

Figure 3 – Per Capita Water consumptions per day

The world population in 2003 was around 6 billion and we are now over 7 billion, and it is expected to grow over 9 billion by 2050. With limited amount of fresh water availability – only 3% of all water available is fresh water [12] – there will be a very high demand for potable water, thus the need to push the per capita consumption lower. Due to climate change and other industrial impacts, the amount of fresh water available is also likely to decrease, which would make the situation to get even worse. So using the existing water for a larger population means much less per capita water available and usage. US being the largest consumer and with a growing population, it is imperative that we reduce the per capita consumption. This water management research paper and the proposal to educate students and public through the latest technology and media is a very significant step towards lowering the per capita home water usage by the use of Web, gamification, and mobile App.

Details of individual home owner water usage history resides first with a home owner and most importantly with the utility (city, county or private water supplier). In order for the home owner to see the impacts water savings through the game app, it is important to have access to this data. Working with the real user data will make the results of the game more meaningful to the user. These will be further discussed under gamification and mobile application sections below.

Sustainability Benefits of Water Conservation

The benefits of water conservation go beyond just overcoming a seasonal shortage. Conservation is to realize the modern definition of sustainability supporting the 3 Es – Environment, Economics and Equity. It is important to clearly understand how *water and sustainability* are intertwined and how the 3 Es of sustainability are affected with water usage and the savings. This section will discuss the impact of the 3 Es as it relates to water usage (and savings) and the *gamification* section below will demonstrate and quantify these benefits starting with a single family home and then spreading it to the community, region and society at large through mobile app.

Environmental Impacts

In many parts of the world and CA is no exception – water is sourced not only from rivers and lakes (man-made and natural), but a significant amount of water is pumped from underground aquafers (groundwater). This is not an uncommon source for agriculture and cities in the western US, but also in many urban areas in the world. In modern societies, fight over water rights between states/provinces within a country or between countries is not uncommon. It has also been recognized and documented that water is being pumped from the aquafers at a faster rate than they can be replenished (or recharge) by rains. The lack of precipitation is not replenishing them even at their so called *normal rate*. According to US Geological Survey (USGS) [14] – pumping groundwater at a faster rate than it can be recharged can have negative effects of the environment and the people who make use of the water. Some of the negative effects include: drying up of wells, reduction of water in streams and lakes, deterioration of water quality, increased pumping costs, land subsidence (or sinking) and saltwater intrusion (closer to the oceans).

Water needs to be moved from its source to the place where it is needed – in most cases water is pumped using electrical energy (as opposed to natural flow). According to CA Energy Commission up to 19% of total energy in CA is spent in moving water, and it is higher in southern CA since some 80% of the supply comes from the snow melts of northern CA. Moving a large volume water and pumping across mountains causes a lot of environmental damage including damage to the natural lives of fishes – Salmon and Delta smelt [15].

The energy needed to pump and move the water has to be generated and it takes coal or oil or gas or other fuels to generate electricity, which in turn produce environmental pollution. According to a Natural Resources Defense Council report, it takes about 3,000 kWh of energy to move one acre feet of water from the Sacramento delta in northern CA to southern CA (e.g. San Diego county), and another 2,000 kWh of energy to move one acre feet of water from Colorado river to southern CA [16]. As we know, most of the energy is generated by burning coal – which is the worst polluter and generates Green House Gases (GHG) and mostly Carbon di Oxide (CO_2) which are very detrimental to the environment. According to EPA, on an average 1 kWh of energy is equivalent to GHG emissions of 1.54 lbs. [17].

By reducing the amount of water that is moved – through conservation much of the damages to the environment can be reduced and perhaps in some cases totally eliminated. The savings directly result in less pumping and movement of the water which results in GHG emissions reduction, which is also an advantage to the environment.

For example, there are about 300,000 homes in San Diego which use about 400 gallons of water on the average per day. If each house even save as little as 5% of its water consumption per day, it would be 600 gals/month, or 180 million gallons for the city per month. The broader impact would be an estimated savings 16.7 million KWh of energy and avoid some 25.7 million lbs. of

GHG (CO_2) emissions. This is equivalent to taking about 2,144 cars off the streets for ever. A huge benefit to the environment.

Economic Impact

In order to understand the economic impact of water and water savings for a single family home, we first need to look at how cities charge single family home usersThere are two parts to water charging – the actual cost of water, and the cost of city services added to the water bill which depend on the usage (e.g. sewer charges) and some fixed base charges (e.g. meter charges). It is to be noted that with the drought conditions, San Diego has raised its water rates by 7.5% for 2014 and is expected to do the same for 2015 [18]. In many major US cities, water rates were increased by an average of 6% for 2014.

Table 1 below shows the monthly consumption in gallons for different per day usage. As noted above, with EPA's average estimate of 400 gallons per day, the monthly consumption as shown in Table 3 will be 12,000.**Monthly Gals, for 30 days**		
@350 Gal/day	@400 Gals/day	@450 Gals/day
10,500	12,000	13,500

Table 1 – Monthly water consumption at different levels of Daily consumption.

It is clear from above data that at 400 gallons per day usage, the customer will be in the third tier. For the purposes of this research paper and for simplicity, the per-gallon price for our calculations used in *gamification* will be the average of the three tiers and that comes to $0.0060339 per gallon. In gamification we will apply this average rate to three different consumers as shown in Table 3. The city overhead cost is roughly about the same amount on a per gallon basis. So the real cost of water delivered to the end customer will be $0.0120677 (roughly little more than one tenth of a cent per gallon).

From an economic perspective, a household that uses 400 gallons/day (12,000 per month) – a saving 10% through conservation measures results in a saving of 40 gals per day and 1200 gals per month. The cost reduction in the home owner's bill will be $14.48 per month. In general it will not be difficult for most household to reduce the consumption by 20% by spending a reasonably small amount of money (less than $100) for leaks and faucet washer replacements and such. This is quite a return on investment. Gamification section below will demonstrate these aspects and also explore many other options to reduce consumption with some spending money.

Equity Impact

Reduction in water usage by households in a city will mean moving and processing lower quantity of water resulting in the following equity benefits:

- Existing water can now be distributed more equitably across larger population
- Pumping less from the aquafers means more water for the future generations

- Utilities giving rebates to home owners to replace their old clothes washers, toilets and kitchen faucets – applicable to all home owners in an equitable manner
- Rebates resulting in a strong potential to create new jobs for more innovative tools and appliances for efficient use of water at homes
- Overall better health to the public since lower amount of CO^2 is emitted to the atmosphere.

The quantification of equity impact is a direct derivation from the above two areas, namely, environment and economics. **Gamification in Teaching Sustainability and Water Management**

The modern definition of sustainable development is from the famous UN Commission report in 1987[19]. This report defined sustainable development as follows:

"Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs."

The report also further clarified by stating that technology and social organization can be both managed and improved to make way for a new era of economic growth. This definition and clarification resulted in our current approach to the topic through the 3 Es – Environment, Economics and Equity – these were briefly discussed earlier showing the relationship to water conservation.

Teaching the basics and advanced topics of sustainability in higher education is still in beginning stages. For many, it is difficult to master these concepts, especially the idea of 'Equity' (or social justice). Along with the theory, teaching the 3 Es with some specificity and quantification goes a long way for students to understand the concepts and to implement them. More than half of Fortune 500 companies are on the bandwagon to be sustainable and many release their annual Corporate Social Responsibility (CSR; sometimes the report is known as Global Responsibility Report or Global Citizenship Report) in which all the actions they are taking towards the 3 Es are explained. In fact, shareholders (and public) are demanding it.

One of the interesting programs in our department is the graduate program in sustainability management. We teach and train our students on a variety of topics relating to sustainability so they would be leaders in the corporate or Non-Governmental Organizations or in the governments. It is no secret that US Federal government with its EPA is strongly pushing forward with many rules and regulations to help the 3 Es – and these are also discussed in the program courses. It is also our belief that every student we teach and empower will have a large impact not only in the work place but will have a larger impact within their own families (home owners) and friends – this is one of the best ways to spread the word on sustainability.

Prior research has clearly demonstrated that student learning through games – or *gamification* - makes it more interesting, fun and improves retention [20, 21]. A well-known business school which teaches *gamification* defines it as follows [22]: *Gamification is the application of game elements and digital game design techniques to non-game problems, such as business and social impact challenges.*

In order for students to grasp and quantify the sustainability concepts, *gamification*– was introduced to teach the course learning outcomes through student created games in the graduate sustainability management program. Students will design, create and play a game to demonstrate the *sustainability* nature of the project as it applies to the 3 Es. Gamification is introduced in the very first course of the program to help the students get a strong feeling about sustainable development – its implementation, quantification and interpretation. This also helps them to articulate this difficult topic in their discussions. In order to get the students to understand the *gamification* concept and how it can be implemented for sustainability course learning outcomes, a Home Water Management (HWM) game was developed by the instructor. The game was demonstrated to the students and the students were given the opportunity to actually play the game in the class – in their very first class. The assignment to the students is develop a game (or adopt an existing game) to demonstrate their course project on sustainability management (student teams choose their specific area for the project – energy, water, waste, etc.).

The HWM game has two major parts – a game board for the actual play and an engine (usually an Excel spreadsheet). Like all games, the design will include game rules, resources, strategies and how a winner will be decided. The water usage, conservation and other details relating to water was discussed in detail above. The game is set up to demonstrate exactly these aspects and give the students a deep appreciation of the 3 Es of sustainability. The engine uses all the data that presented earlier on water costs and other data (e.g. cost of repairs, etc.) and will automatically calculate and display the results in a dashboard for each player.

This particular game, called Penny Drops©, has three players – Tom, Joe and Sue - and each of whom is a single family home owner consuming three different levels of water – 350, 400 and 450 gallons per month respectively. The game board designed is shown in Figure 4 below.

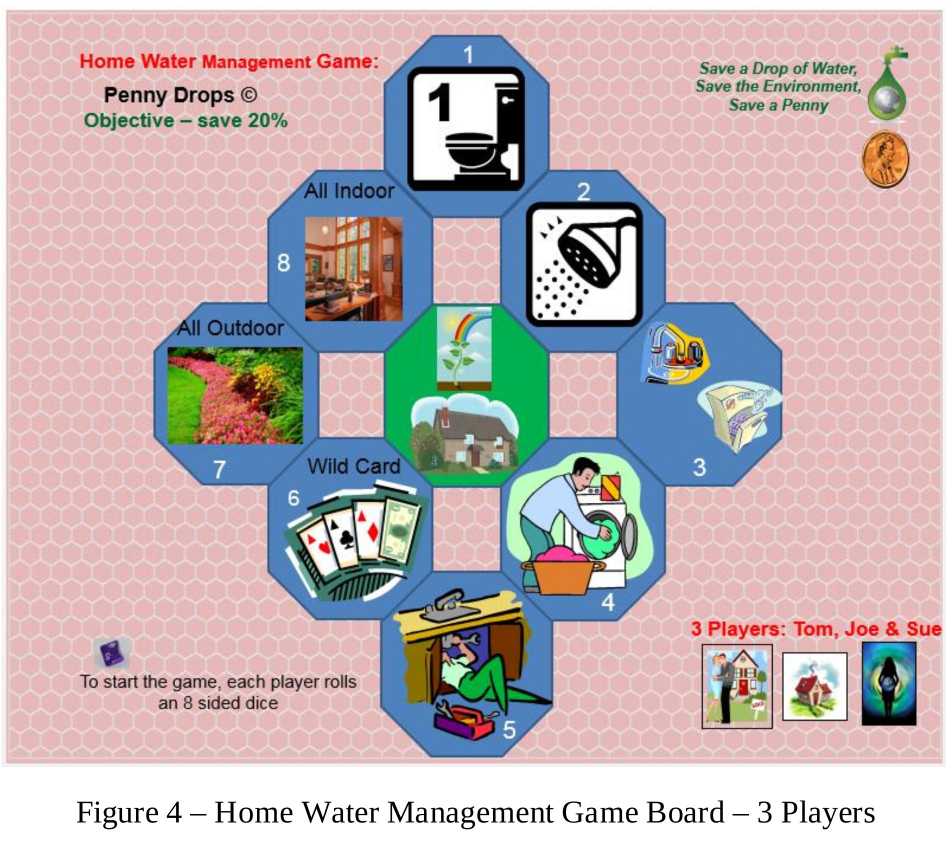

Figure 4 – Home Water Management Game Board – 3 Players

The main design-feature of the game-board is that it reflects the major water usage in a single family home in the US. The different landing-areas are self-explanatory (through the icons on them) on the water usage in a household. Water end use distribution was discussed in detail earlier and these will be used here. In addition, for the game fun parts – like any board game, there are some randomness introduced – like the Wild Card, all Indoor or all Outdoor landings – the player can pick any of the other areas to implement in that round. There are eight areas to land – each is an opportunity to save water with more than one approach (strategy) and thus the game has 8 rounds of play. The game-board was created using MS PowerPoint tool. The game is played with an 8-sided electronic virtual dice [23]. The game also gives seed money of $500 to each player. This money is a *resource* and the players are free to spend it on purchase of new items or do repairs/fixes that would help reduce water consumption (e.g. low flow faucets, replace an old high water usage toilet to a low-flow toilet, replace sprinklers, repairs to fix leaks, etc.).

Playing the Game Board and Engine Feedback/Results

The objective of the game is to reduce the household monthly water consumption by 20% and the resource (spend money) effectively to achieve the reduction. The winner would be the one who comes closest to saving 20% of monthly water consumption (or exceeds it) and also has the most money left over. The game involves strategic decisions to be made by each player when they land in of the 8 landing areas driven by rolling of 8-sided dice.

For each landing on the game board per the dice, the player will use the engine and per his/her strategic choices to calculate the water savings and other benefits (3 Es). The dashboard displays immediately the results. See figure 5 below – it is an example of the dashboard for the 3 players at an instance of play. A part of the engine for one of the players, Tom – the Excel spreadsheet is shown in Appendix 1.

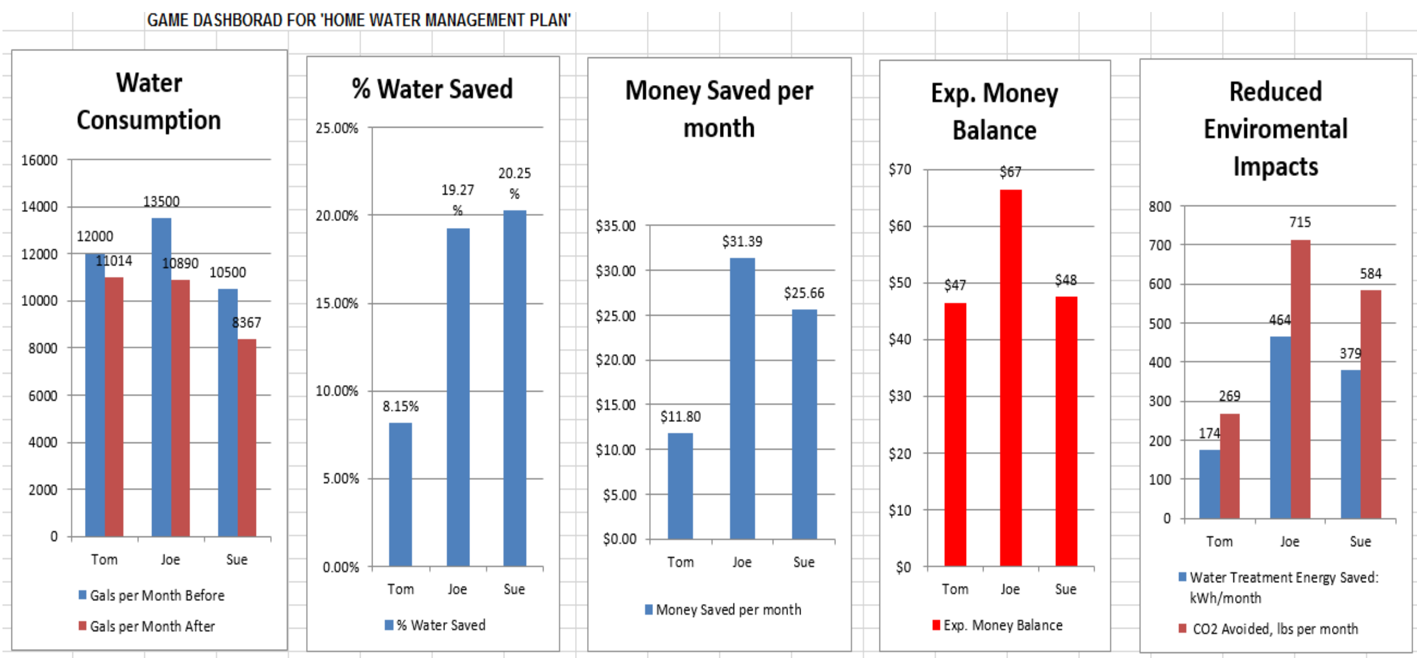

Figure 5 – HWM Game Dashboard showing the progress - quantified data.

It is to be noted that this game developed and demonstrated by the instructor, and played by the students is for demonstration purpose. Each student team will then design/create, develop and demonstrate the sustainability attributes of their chosen project. The topics ranged across the board - energy, food, agriculture, waste, etc., for a company or other end users. This engine is designed for manual entry so the students know exactly all the elements that go in to calculating the savings. In a real mobile app, there will be a default data set and will also give the option for the user to enter data.

At the end of the course, an anonymous student survey was conducted to get feedback on the gamification approach and its benefits (motivation, communication, retention, etc.). On a five point scale (5 being the best/highest rating) – all aspects of gamification got over a 4 rating (highest was for gamification helping to demonstrate difficult concepts of sustainability at 4.7). This gives the impetus to take this to next levels – mobile App, Website etc.

Collaboration with the Computer Science Department

It was important first to prototype HWM game using a website implementation. In collaboration with the Computer Science department in our school, the next step taken was to prototype this in capstone project for an undergraduate class (final course and project before graduation). The student team successfully prototyped the HWM and the approach through a website, and they also took some new and independent innovative approaches for strategies. The website and the game was demonstrated to the class in their final capstone presentation. The game-board designed for this capstone project is shown in Figure 6 below. The engine was running in the background and response was instantaneous.

Figure 6 – HWM Web Implementation: Game Board by a Student Team (capstone project)

In order to play this student created game, the player(s) would log in to the website, enter player(s) game, and then click on the specific icon after an electronic dice roll, and that would open up new screen options (or strategies) for water savings. The player would choose an option to save water and the engine will calculate all other output numbers as shown in the dashboard in Figure 6.

It is to be noted that all data in these illustrations are per assumed water usage and distribution as discussed in the earlier sections. In this paper, we take this to the next level through a mobile application by actually using a home owner's real data with a link to be established with the water supply authorities (city or county or other suppliers). These will be discussed further in the mobile app section below.

Mobile Application

The research collaboration with the Computer Science department is ability to take HWM game to another lever with the implementation of a mobile App. This section will cover some of the benefits of introducing mobile App in class room and then discussing how it can be extended to include the actual owner specific data on water usage from water supply authorities. The section will also discuss some of the benefits of mobile App and an architecture to implement the same for HWM plan.

The mobile Apps can leverage learning beyond the class rooms acting as supplements which fill several gaps in the learning process. The case for using mobile Apps as course supplements, their advantages and their desired features have been researched and published [24]. Well-designed Apps would be entertaining and engaging, and would facilitate exploration and experimentation. In this section, we present the motivation for having a mobile App component for the HWM plan and its benefits in a learning environment. In the following sections, we present the architecture of the mobile App and the desired salient features of the mobile App and the major UI (User Interface) factors for it to be effective.

The scale at which the general public is accepting and using mobile Apps for different aspects of life, living and related activities has been phenomenal to say the least. The ultimate goal of this research would be to extend the HWM mobile APP beyond the class room (which provides initial test bed) to the general public by establishing relationships with water supply authorities. This approach helps not only in '*scaling*' the awareness, but as a real tool that the home owners can use - saving money, environment and promoting the 3 Es of sustainability. The following sections will describe the mobile App as course supplements and the further research and to extend it beyond the class room.

Motivations for mobile Apps as course supplements

We briefly describe below some of the major motivations for incorporating mobile Apps as course supplements, with the major objectives of generating and sustaining interests in the subject matter and facilitating self–learning. For example, a mobile App can employ a combination of problem solving, videos, audio clips, animations, etc., as appropriate, and offer an engaging supplement to class lectures and textbook materials. With the information overload in a typical course in recent times, mobile Apps are expected to facilitate the assimilation of content more effectively

Since the Apps are inanimate, the slow learners would not have hesitation to use them repeatedly to learn or reinforce concepts they have particular difficulty with. This, combined with the entertaining/engaging aspect, would be a motivating factor for using the App for learning. The incorporation of appropriate positive feedback would provide encouragement in addition to motivation.

By building into the Apps suitable self-assessment of learning, the system (Apps) can learn about the user's difficult areas which need improvements, and focus more on those areas by providing more examples and assessment questions as needed. Thus the Apps can be personalized to the different learners.

Benefits of mobile Apps as course supplements

Several of the major benefits of using mobile Apps as course supplements are shown in Figure 7.

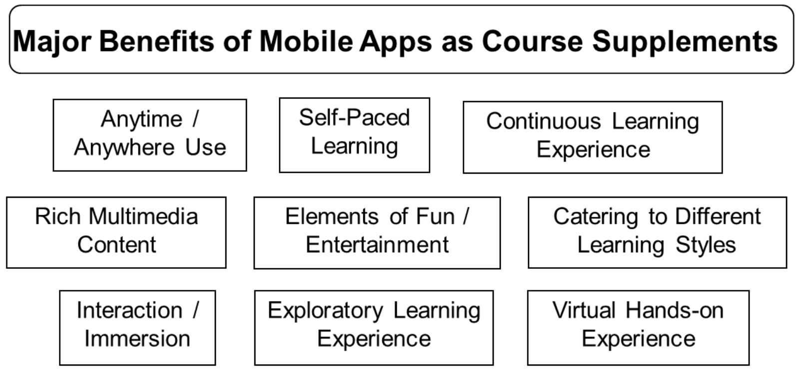

Figure 7. Major benefits of mobile apps used as course supplements

They facilitate 'any-time', 'any-where' learning due to their inherent mobility and Web access. Class times are structured and limited. There are demands on the teachers for the coverage of topics. There are only certain amounts of content that could be delivered in a limited time. The mobile Apps supplements would be a boon for students by helping them catch up and understand the course material at their pace. The mobile Apps also facilitate continuous learning experience, where in, a learner may go beyond the class room or course and learn additional related things based on one's interests.

Thoughtfully designed Apps can support customization/personalization to cater to different learning styles. The well–designed Apps can cater to short attention spans by presenting a logical unit of content one screen (or a few screens) at a time.

The Apps for learning could be made interactive and engaging using commonly available multimedia technologies. The Apps can be designed to make learning fun by the judicious combinations of text, graphics, audio, video, and animation. In addition, they may use elements of games to provide highly engaging and virtual hands–on learning experience. These will help consolidate important principles and concepts of a course and lead to enhanced retention.

Several of these attributes above were the same or similar to those discussed earlier when *gamification* was introduced earlier demonstrating commonality of attributes between the two approaches.

Mobile App Architecture

This section presents the architecture of the mobile App to be used as part of teaching the various aspects of home water management. Our intent is to use a highly interactive and game–like approach, where the 3 Es of sustainability – Environment, Economics and Equity are demonstrated. Students use this approach to quantify conservation of water and other resources as well – e.g. energy. The approach used on a desktop in another course has received very favorable feedback from the students.

The mobile App is interactive with game–like features. It has three main components – (a) computation/evaluation engine, (b) database interface, and (c) user interface. The overall architecture of the system is shown in Figure 8 below.

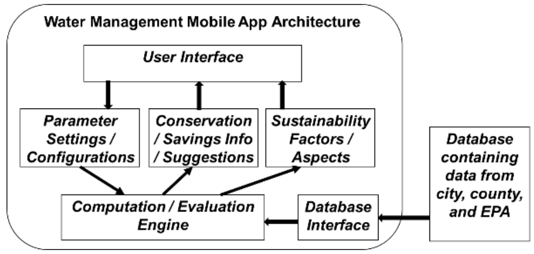

Figure 8. Architecture of the mobile App for home water management

The computation/evaluation engine forms the core of the mobile App which performs all the required computations. Every aspect of a typical household water usage is modeled in the engine to instantly calculate the water consumption and cost. Most general household water usage is included in the model (toilets, kitchen, bathroom, landscape, clothes washing, etc.). The engine is designed to contain a default household data. The users can also easily input (through user friendly GUI) to customize the data with the actual parameters or configurations of experimental scenarios. Some examples of parameters / configurations are the number of bedrooms, number of bathrooms, pool, Jacuzzi, the number of adults and children in the household, the sizes of front and back yards, the size of lawn, use of irrigation system, the level (percentage) of savings desired and the desired proportions of where the savings come from, etc. The computation/evaluation engine uses the actual data/information from the city, county, and EPA (Environmental Protection Agency) contained in a database. Based on the input parameters and the actual data from the database, computes the conservation–related data and also provides several suggestions.

The user interface of the mobile App is an important component which supports high level of interactivity, game-like features, and support for various scenario evaluations. The user interface provides facilities for the user to change several usage parameter(s) and see the results immediately. This kind of instantaneous feedback is very valuable in evaluating numerous scenarios quickly, and to determine the choices suited to a given set of constraints.

Using the real–world database and an engaging user interface supporting numerous scenario evaluations, the mobile App supports engaged learning of the complex interrelationships of numerous parameters in water conservation in the bigger picture of sustainability.

Desired user interface factors of the mobile App

The desirable UI (user interface) factors that we propose to be incorporated in the mobile App are shown in Figure 9 and are briefly described below.

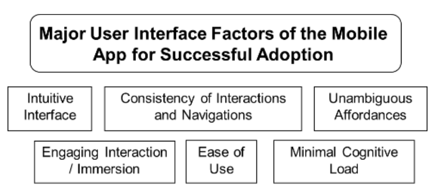

Figure 9. Desired major UI factors of the mobile App

Intuitive interface. An intuitive interface does not require detailed instructions and does hardly have any learning curve. The elements of the interface are thoughtfully designed and judiciously laid out. This makes it 'natural' for users to use.

Ease of use. An easy–to–use interface is important for the App to be appealing. The interface should hide the underlying complexities of functions and operations to enable the users to use the App effectively to accomplish the intended uses. The average number of (atomic) user actions (ex. key clicks / taps) to accomplish a task is minimal.

Unambiguous affordances. An affordance is a property of an object, or an environment, which allows an individual to perform an action. In the context of human–computer interaction (HCI) it indicates the easy discoverability of possible actions. In the case of mobile Apps, the affordances should be unambiguous to enable selection of actions to achieve intended operations, and eliminate/minimize the number of backtracking.

Engaging interaction/immersion. The interactions should be designed to be engaging and immersive to sustain the interest of the user to the point of finishing the tasks. This is especially important considering the fact that the attention spans of mobile users are rather short.

Consistency of interactions and navigations. The interactions and navigations should be consistent across tasks and functionalities. This makes App easy to learn and to use, with reduced cognitive burden.

Minimal cognitive load. The average number of levels in the navigation to accomplish a given task / functionality contributes to the cognitive load. Minimal cognitive load is extremely important for acceptance of mobile Apps, especially when used as supplement to learning. With a low cognitive load, the user can focus more on the content and the learning aspects.

The above factors are key to the effectiveness of the use of the mobile App in the related courses to grasp the impacts of the factors in HWM. They are also equally important to impart education and awareness about HWM to homeowners.

Conclusions

The increase of world population, especially in the urban areas, along with the climate change impacts brought on by a warming planet (due to GHG) has made water conservation a necessity. Water conservation is also a part of the bigger picture of sustainable development promoting better and improving Environment, Economics and Equity (3 Es of modern sustainability). Water usage in a single family home in the US is one of the major ones among the various water usages in the big urban areas. Cities and counties have introduced several water conservation programs and rebates. Although they are seeing limited success, majority of home owners do not have the knowledge and awareness of their own end use consumption and distribution. There is lack of useful, informative, and engaging mobile Apps to educate the public and make them aware of home water management (HWM) approaches.

This research paper described *gamification* as a method of teaching the concepts of sustainability, and in particular, water conservation. It also introduced the motivation, design and use of mobile App as a means of learning about HWM by students in classrooms. The ultimate goal of this research is to be able to deploy the mobile App to single family home owners, and public at large to raise water conservation awareness, save water. The deployment of the App will be through water supply authorities (city and County).

Future research and implementation includes demonstration of the prototypes to water supply authorities not only to get their feedback, but to initiate steps to integrate the App in their service deployment after some field tests. Energy companies are further ahead in this area with a Web implementation which shows a home owner can see energy usage in their neighborhood. This implementation will leap-frog and do more for home owner education and public in general.

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Appendix 1 Part of the Excel Engine for One Player ©

WorkSheet for Tom's Implementation of the Plan

Strategy - Area of Change	Round #	Type of Work	Unit Material Cost	Total Material Units	Total Material Cost	Unit Labor cost	Total Labor hrs	Total Labor cost	Total Cost of the Option		Calculate Water saved per unit/mont	% of Water saved per month	Cost of water Save per month	Comments - enter any details
TOILETS	Round 1	Replace Toilets	$150.00	1	$150.00	$85.00	2	$170.00	$320.00		180	1.50%	$2.17	
	Round 2				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 3				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 4				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 5				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 6				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 7				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 8				$0.00			$0.00	$0.00			0.00%	$0.00	
					$150.00			$170.00	$320.00		180	1.50%	$2.17	
SHOWERS	Round 1	Shower heads	$35.00	2	$70.00	$75.00	0.5	$37.50	$107.50		150	1.25%	$1.81	
	Round 2				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 3	Adjust			$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 4	Reduce shower time			$0.00			$0.00	$0.00		180	1.50%	$2.17	Behavioral Change
	Round 5				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 6				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 7				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 8				$0.00			$0.00	$0.00			0.00%	$0.00	
					$70.00			$37.50	$107.50		330	2.75%	$3.98	
Kitchen-Faucets Dishwasher	Round 1	Put Acerator	$3.00	1	$3.00	$0.00	0.0	$0.00	$3.00		60	0.50%	$0.72	
	Round 2	Use of Dishwasher Pattern	$0.00	0	$0.00			$0.00	$0.00		40	0.33%	$0.48	
	Round 3	Reduce running water in faucets			$0.00			$0.00	$0.00		30	0.25%	$0.36	Behavioral change
	Round 4				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 5				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 6				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 7				$0.00			$0.00	$0.00			0.00%	$0.00	
	Round 8				$0.00			$0.00	$0.00			0.00%	$0.00	
					$3.00			$0.00	$3.00		130	1.08%	$1.57	