

Chapter #12

GAMIFICATION AND TECHNOLOGICAL LITERACY Educating electricity users

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ABSTRACT

The staggering technological advances of the last decades and rapid changes in the engineered world surrounding us have led to the emergence of technological illiteracy as a major social challenge threatening to create outcasts. Informal education, a path typically chosen by those who feel marginalized by the formal school system, may be more appealing to children and adults alike since it takes away the pressure of school performance and the stigma of failure. The challenge in creating content for informal learning lies in engaging and retaining the learners in an active mode, in making them truly interested in their learning process and achievements. Gamification technology has been proposed for developing engaging informal education programs targeting technological literacy. A novel methodology for developing gamified applications is proposed which is based on a well established behavioral model. It uses the cognitive model to develop the individual's knowledge base and skills and gamification mechanics for emotional engagement and triggering. This methodology has been used to develop a pilot application targeting electricity users which aspires to educate them in electricity saving, consumption, production and markets in line with the emerging smart grid paradigm.

Keywords: electricity, smart grids, behavioral modification, technological literacy, SMARTEGE.

1. INTRODUCTION

Technological illiteracy is a state of cognitive disequilibrium experienced by an individual where his or her knowledge and skills are not sufficient or necessary to account for and interact with the world he or she lives in. At a social level, it blocks potential for further progress, raises barriers, leads to social exclusion and is ultimately counterproductive.

Technology goes hand in hand with the history of mankind and the evolution of human species as it spans all activities and objects developed by mankind. The dazzling pace of the scientific and technological progress, particularly in the second half of the 20th century, has left educational systems trailing behind gasping for breath in their effort to catch up, and a large part of the population lost in an ocean of awe and ignorant bliss. More often than not, the former give up the unfair struggle and focus in providing solid, conventional tools that will hopefully enable the future citizens to learn, find out for themselves and catch up on their own. More often than not, the latter are disenchanting by the educational content which seems to reflect another era than the one they are living in and end up brushing aside the tools offered to them, opting for the easier path of mass information rather than that of education.

In this landscape, informal learning methods may be a valuable companion, alongside formal and non-formal education material and structures, in the struggle against technological illiteracy and social exclusion. Because, *“if we all occupy different positions in a vast, all-inclusive circle, rather than occupying different levels in different pyramids which are themselves at different levels, then it is impossible to fall from a height and more difficult for movement to be experienced as mortal threat”* (Wilshire, 1990, p.267).

Gamification is a promising informal learning methodology. Loosely defined as a practice of using gaming technology and mechanics in non-gaming applications, it has already found its way in digital applications and marketing. According the Gartner Hype Cycle, gamification has moved from being at the end of ‘innovation’ triggering period (2012) to the maximum point on the peak of ‘inflated expectations’ (2013) to approaching fast the ‘trough of disillusionment’ (2014) and moving towards the ‘plateau productivity’. According to the 2015 chart, the hype is over and gamification is omitted from the chart being considered as a mature rather than an emerging technology in digital marketing.

However, the role of gamification in education is still an open-ended question (Dicheva, Dichev, Agre, & Angelova, 2015). Even though applications have already been developed for both formal education in traditional classroom environment as complementary learning tools or in e-learning and distance learning platforms (Domínguez, et al., 2013; Lee & Hammer, 2011) as well as informal education and behavior intervention or modification (Carr, Taylor, Hunt, & Mejia, 2014; Mohr, Schueller, Montague, Burns & Rashidi, 2014), published results are still inconclusive. It is not clear yet what the appropriate methodology is for gamifying educational content or what type of courses or learning it is more appropriate for.

In this chapter, we aspire to offer a roadmap for developing educational applications for informal learning based on Fogg’s Behavioral Model (Fogg, 2009), a model developed for persuasive design targeting behavioral modification. The methodology proposed uses the cognitive approach (Bloom & Krathwohl, 1956) for capacity building and the flow model (Csikszentmihalyi, 2000) for user engagement through game mechanics. This method has been applied to design an online application for smart phones and tablets targeting the technological literacy and behavioral modification of electricity users in line with the paradigm shift towards smart grids and demand side management (Constantos et al., 2014).

2. BACKGROUND

2.1. Technological literacy and informal learning

According to Piaget’s cognitive child development theory, when a child’s knowledge base can no longer account for the world around it, it enters a state of cognitive disequilibrium and is no longer able to assimilate and process the new knowledge and skills required. This leads to a frustrated state which is believed to drive the learning process towards a new equilibrium point. Though Piaget’s theory is concerned with children developing into rational individuals, and not with learning processes, it may be extended to the cognitive development in adults in the sense that Kant defines enlightenment as “man's emergence from his self-imposed nonage”: when an individual is aware of the lack of knowledge on a certain problem, enters a state of disequilibrium (Kavathatzopoulos, 2001), as in the case of technological illiteracy.

People need a minimum level of relevant knowledge in order not be shunned and benefit from a novel or updated technology or system. Technological illiteracy is a self-sustained condition where lack of understanding and hands-on experience will make a technologically illiterate person less likely to learn through experience and develop intuition and judgment for technological applications (Pearson & Young, 2002).

Technological literacy is a basic transversal skill (Pearson & Young, 2002; ITEA, 2007) that goes way beyond the use of computers or web searches. It is about knowledge and skills as well as ways of thinking and acting that allow people to participate in the world around them in an intelligent and thoughtful manner. A technologically literate person: realizes the pervasiveness of technology; is familiar with the basic concepts important to technology; knows about the engineering design process; understands that there are trade-offs, capabilities and limitations involved in any system; understands there are risks, costs and benefits in the use of any technology; recognizes the dialectic relationship between technology and society; is capable of improving his or her life by solving simple problems and participates actively in decision making processes concerning technological solutions (Pearson & Young, 2002). When a society enjoys a higher level of technological literacy, its members are more immune to opinion forming and manipulation and more likely to apply filters and good judgment in the adoption or use of some technology thus enhancing its positive aspects while blunting the negative ones.

In the quest towards a new equilibrium state, the technologically challenged individual will either attempt to construct the new knowledge or seek it out where it exists. He or she will turn towards educational structures and resources or search for knowledge and/or information through informal channels.

Informal learning is nowadays viewed as a third learning path, the other two being formal and non-formal educational programmes or curricula. It may be defined as the learning taking place, in the absence or in spite of authorized instructors, outside curricula and educational institutions. Informal learning can be (Schugurensky, 2000):

- a) self-directed when purposefully undertaken by an individual or a group and uses knowledge and information resources found in an another person or repository, e.g. Internet, in a self-assisted manner; it is intentional and conscious
- b) incidental when unintentional but conscious
- c) tacit when unintentional and unconscious.

Informal learning, like formal and non-formal education, may build on existing components of our knowledge base (additive) or configure it anew by transforming its base units (transformative).

The value of informal learning in technological literacy is discussed in (Pearson & Young, 2002) while standards for technological literacy are presented in (Standards for Technological Literacy, 2007).

2.2. Informal learning and gamification

According to a survey of the American Society for Training and Development on informal learning (ASTD, 2008) typical practices employed by companies for personnel training include: emails for sharing knowledge (68%), offering employees reading material on an intranet (52%), “fingertip” knowledge (52%), “self-learning” facilities where employees can access learning modules at their own pace (32%), instant messaging (32%), online social networking (31%), peer-to-peer coaching (30%), voluntary informal mentoring (28%), communities of practice (20%), informal networks (20%), online discussion groups (14%), wikis, blogs or other employee-generated content (12%). Such practices are all compatible with gamification design methodologies and mechanics.

In adult learning, motivation may stem from a variety of reasons and engagement must be linked to immediate, tangible results. Gamified applications do not rely on the user's desire for learning and investigation but are relevant to the user's everyday life, experience, and culture through the game narrative, strategy, and clear and precise goal. Gamification learning is a non-linear process like online and self-learning and the mechanics used to increase motivation, engagement and interaction among learners appeal to the cognitive, emotional and social areas of players in a mixed and interleaved way: e.g. when a badge or an award obtained for mastering a given course content and attaining expected learning outcomes is communicated to all other players, it appeals to all three areas.

Similar to a course, a gamified educational application offers levels allowing incremental progress and the design of own learning path and curve through typical gaming practices such as tasks and missions. Assessment is immediate, incremental, progressive as well as fun through game mechanics such as notifications, points, leaderboards, badges, and awards. Social interaction can be as simple as the use of a leaderboard or social media for invitations and messages or scale up to users forming communities and competing in teams. In any case, the social dimension allows the users to tell their own story, motivates them to create an identity through the application thus further engaging them in the process.

3. DESIGN METHODOLOGY

Our approach is based on Fogg's Behavioral Model - FBM (Fogg, 2009) developed for persuasive design targeting behavioral modification. FBM postulates that individuals are convinced to change their behavior on an issue, when three conditions are satisfied: sufficient motivation, adequate ability and timely triggering to implement behavioral change (Fig.1). Motivation, M, and ability, A, can be visualized as two axes defining a plane of possible behavior states, $B(M,A)$ reflecting the various levels of motivation and ability among people. Individual behaviors, $B_i(A_i, M_i)$ occupy various positions on the plane and follow different trajectories to the target. Assuming that behavioral change is incremental, each trajectory is the result of discrete, smaller rather than larger, steps towards the target. To move from, say B_1 to B_2 , triggering must be applied at the right timing. This is when the individual is able and motivated enough to attain $B_2(A_2, M_2)$, i.e. the individual's motivation and ability are higher than A_2 and M_2 , respectively.

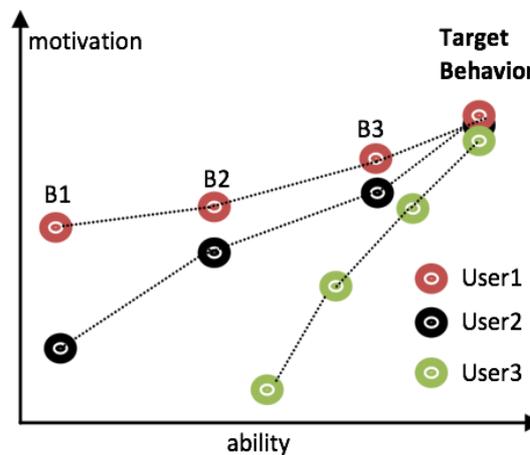
In the context of learning environments, the target is a learning outcome of a course. Learners, who are not equally motivated or able at the beginning of the course, are allowed and encouraged to follow personalized trajectories towards attaining the predefined goals. They are allowed to do so by the availability of educational content supporting various trajectories and are encouraged by appropriate and timely triggering.

3.1. Persuasive technology and learning environments

According to FBM, the ability of an individual to implement change is determined by the simplicity of the steps required to accomplish a task. It is a function of six variables which can be thought of as finite resources: *money, time, physical effort, mental effort, social deviance and non-routine*. Each one is associated with a cost whose value is different for each individual. The ability function can be modeled as a cost function whose value is determined by the variable with the highest cost at any given time: e.g., if change in a given direction by an individual requires investment in both physical effort and money but the individual is in a dire financial situation, the height of the barrier preventing the individual

from changing is determined by the lack of money. If the cost function C of change is given by $C = \max\{\text{money cost}, \text{physical effort cost}\}$, to facilitate change, C must be reduced either by decreasing the required investment in money or by increasing the ability of the individual to invest the required amount. In other words, to facilitate change, the height of the barrier as perceived by the individual must be decreased. This can be accomplished either by decreasing the barrier height in absolute terms or by raising the individual's level.

Figure 1. FBM's plane of behavior states and trajectories towards the target behavior (left). The 3D technological literacy space (Pearson & Young, 2002) (right).



In the context of learning environments, the ability is determined mainly by the mental effort required to accomplish a task. For the learner to take steps towards achieving a given learning outcome, it is necessary to mainly increase his/her capacity through education. In this process, it is important to remember that the cost function associated with each step depends on all six variables. Decreasing the mental effort required to attain the next level in the learning process, should not have a cost in time, money, physical effort, social deviance and non-routine higher the cost savings achieved via capacity building.

In (Pearson & Young, 2002), technological literacy is conceptualized as a three-dimensional space defined by axes, x: ways of thinking and acting, y: knowledge, z: capabilities (Fig. 1). A technologically literate person moves on a trajectory towards higher values of all three variables. In terms of the FBM model, the horizontal 'ability' axis corresponds to the y-z 'literacy plane' defined by capabilities and knowledge. Movement along the 'ways of thinking and acting' axis of technological literacy corresponds to the behavior modification trajectory of FBM after motivation and triggering is introduced to engage the user in the process. The latter is accomplished through game mechanics along the lines of the 'flow' model (Csikszentmihalyi, 2000).

The motivation of an individual to learn and/or implement change is increased leveraging three basic emotional dipoles: a) the pleasure/pain motivator which has an immediate effect on the learner, e.g., high/low grade, answer/not answer a question b) anticipated hope/fear which has a long-term effect, e.g., move towards/away from mastering a skill or conquering a learning outcome c) social acceptance/rejection, e.g., high/low ranking in class, popularity among a group with a common target outcome.

Depending on the ability and motivation of an individual appropriate triggering must be applied choosing from: a) sparks, messages for unmotivated individuals b) facilitators, activities designed for individuals of low ability c) signals offering guidance and advice to individuals of sufficient motivation and ability (Fogg, 2009).

User1 in Figure 1 is highly motivated but is lacking ability. User1 will benefit from facilitators and content guiding him/her through the learning process, making sure he/she is not disenchanted or discouraged in the process by appropriate notifications and encouraging sparks. User2 has low ability as well as motivation. In this case, all types of triggering should be applied to guide User2 towards the target. User3 has high ability but very low motivation. Though there is still educational content to be covered, he/she must be first engaged in the process using all three emotional dipoles.

The application must offer all these options to the users and guide them towards the appropriate direction where, in turn, they will be able to choose features they feel more comfortable with. Gamification processes and technologies are used to do that.

3.2. Gamified cognitive learning

The application learning content is developed following the cognitive approach and Bloom's taxonomy (Bloom & Krathwohl, 1956) in agreement with the six levels of the learning pyramid: know, understand, apply, analyze, evaluate, create. These levels are used to determine the learning outcomes, develop learning material and design the game levels.

The more types of material are offered, the more flexibility is given to the user to draw own learning path: notes, reading material from external sources, useful links, short videos, sounds or other audio material, figures, assignments, quizzes, tests, are all found in a library organized according to Bloom's taxonomy. User generated content may also be allowed which will be moderated by the application administrator and subject to game mechanics: a user uploading learning content will earn points in the game according to the quality, relevance and level of the content, the usefulness of the content to fellow students, etc.

To decide on the choice and use of game mechanics the motivation matrix of the application is constructed (Constantos et. al., 2015) where the following phases must be identified: a) acquisition, during which users are first attracted and engaged in the learning process; the phase's duration, content and mechanics depend on the type of learning b) education which spans an educational application from beginning to end c) attraction, during which personalized features are introduced; based on the ICT tools available, data-mining techniques may be used for more accurate learner-user profiling d) involvement which starts later in the game as capacity increases and the user feels more confident to advance at higher levels and tackle harder tasks e) motivation which spans the application from beginning to end, using all types of FBM motivational dipoles in conjunction with triggering f) conversion is an important phase in applications targeting behavioral modification where the user attains target behavior; the content in this phase is clearly target oriented addressing well educated and well motivated users; in other educational applications, this phase refers mainly to the final level of the cognitive pyramid g) conservation is also a phase of applications targeting behavioral modification; in educational applications, the engagement stops when all learning outcomes have been achieved and this phase is not required and i) excitement aiming to make users return to the game by renewing the content; this phase may not be required in educational applications.

The game mechanics used must serve the defined learning outcomes and motivation phases. Once the narrative and goal of the ‘game’ is determined, its levels must be defined in a clear and transparent manner. These must be of increasing difficulty and compatible with the learning material organized according to Bloom’s taxonomy. Sparks, facilitators and signals are developed for each level. The counters of the game are decided next and points are assigned to each user action in a way that serves the learning outcomes and the desired goal while maintaining the user in the ‘flow’ zone. Tasks and missions appealing to the cognitive, emotional and social area are designed as well as badges and leaderboards to reward the users and enhance competition among them.

4. ELECTRICITY GRID AND USERS

Over the last two decades we are witnessing an accelerating paradigm shift in electricity grids and markets. The power grid is required to abandon the traditional supply side management in favor of the demand side management of a ‘smart’ grid. The shift is triggered by the pressure for energy saving and low carbon emissions on the one hand and electricity market deregulation on the other. It is enabled by technologies such as renewable energy sources (RES) and distributed micro-generation, wireless networks, telemetering and telecontrol. The smart grid allows two-way communication in real time between the provider and the user or the producer and the system operator generating data to be used for the optimum operation of the system. The emerging smart electricity markets are expected to provide the necessary feedback mechanisms (Neuhoff, 2011).

The user of the smart grid is therefore an active agent interacting in real time with the grid and the markets rather than a passive consumer receiving and paying the electricity bill on a regular basis. In this new techno-economical reality, the majority of electricity users, are technologically challenged if not totally illiterate. A recent survey has shown (Constantos et al., 2014) that electricity users lack fundamental knowledge and skills: they cannot read their electricity bill, they do not know what a kWh stands for, they are not aware of their energy profile and needs, nor can they estimate their consumption never mind making informed decisions on RES installations towards net zero energy building (nZEBs) which are one of the EU 20-20-20 targets.

Their inability to function in the emerging paradigm hinders the uptake of technologies and policies that will facilitate the transition to the demand side management, or even adopting new habits in light of the much advertised energy savings. Due to marketing, they respond positively to buzz words such as RES, photovoltaic's, smart meters, etc, but are not aware how these technologies may affect their lives, the limitations and trade-offs involved or their value for money.

In light of the above, we have developed (SMARTEGE) a gamified online application for smart phones and tablets targeting the technological literacy of electricity users using the methodology described in the previous section. For example, let us assume that we want to train users to purchase online and in advance the electricity (kWh) they will need for the next day, week or month. To accomplish that, they must:

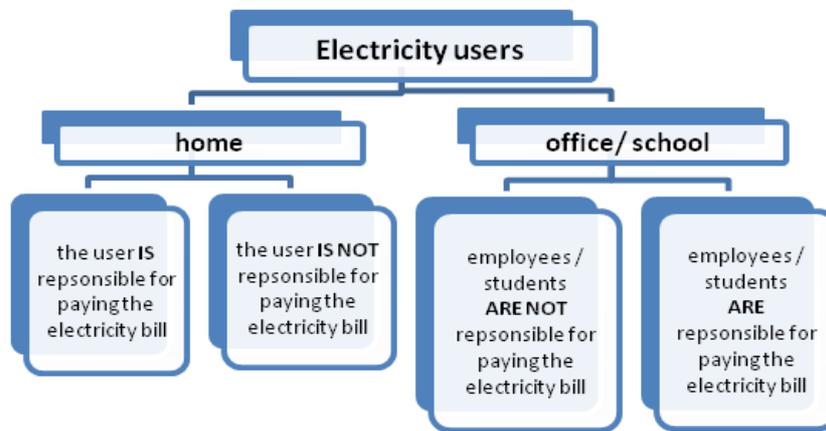
- be able to do so, i.e. to know where the relevant application is, how to use it, the basics about electricity generation, consumption, saving and billing, the energy profiles of their appliances over a period of time, how to compute the electrical energy necessary for the time period of their choice, etc.

- be motivated enough to engage in the process because of saving money while increasing comfort levels; better income and energy management; benefits from the electricity provider; avoiding running out of credit and risking a black out; being part of a wider online community exchanging info and tips.

- be triggered at the right timing by messages reminding them that credit is running low or appliances are left on standby mode; notifications about competitive kWh pricing, tips on navigating and using the application; warnings about excessive electricity consumption of appliances etc.

SMARTEGE’s learning content takes into account the following user types (Fig. 2): users paying for electricity use, such as parents or office managers, and users not responsible for paying the bill, such as kids, students or employees.

Figure 2. Electricity user types.



The expected learning outcomes for the SMARTEGE user, as a consumer, are to: know the basic notions and definitions of electrical energy; understand the relationships between the electrical energy quantities; apply this knowledge to a building’s energy management; analyze the energy profile of a building; evaluate the energy performance of a building; create energy efficient scenario for energy management.

The expected learning outcomes for the SMARTEGE user, as an electricity producer and market agent, are to: know the basic notions and definitions of electrical energy production and market; understand the relationships between the electrical energy production and consumption quantities; apply this knowledge to the management of small RES installations and electricity trading; analyze the techno-economical profile of a RES installation; evaluate the performance of a RES installation; create energy efficient scenario for RES management. The educational content in the form of tips, definitions, explanations, questions and reading material is developed according to these objectives.

The application presents a 3D virtual environment that emulates the basic daily functions and actions of an electricity user in a house and an office building, in real or accelerated time. Using gamification mechanics, such as badges, leaderboards, levels etc the user is gradually trained to understand the energy profile of appliances and equipment operating in the virtual building with respect to the set points defined by the user, to evaluate the effect of his/her actions and habits on it, to analyze the costs and benefits

associated with energy upgrading or saving tactics. At a higher level, the user is allowed to virtually produce electricity in order to attain the ultimate nZEB goal. The user's ability is improving through knowledge content offered in various forms, such as tips, information, reading material, quizzes, exercises, and is guided through the process with appropriate triggering while being motivated by counters, reputation points, leaderboards, badges. All types of motivators are used while special emphasis is given in the social dimension: the user is interacting with other users and is allowed to exchange information or messages through social media. At advanced levels, with the purchase of appropriate hardware, the user can emulate, monitor and control the electricity use and production of a real building.

The pilot version currently being tested has four levels. The first level is a 'Tutorial', at the acquisition phase, which offers a virtual 'tour' of the application and introduces most of the game elements that will be encountered in the game. The user is asked to answer a set of quizzes to accumulate points. If users fail, they are prompted to read appropriate educational material available in the 'library' and take the test again.

The second level is the 'Flat' which unlocks once the tutorial is completed successfully. The user is invited to select from the application's "inventory" typical home electrical and electronic appliances and position them in the virtual flat he/she is going to manage. With the help of appropriate triggering and educational material, such as tips, recommendations, explanations and definitions, the user is led to schedule the operation of the selected appliances to optimize the electricity consumption as well as the comfort level in the Flat. The user may increase the energy class of all buildings under his/her control by replacing existing appliances and devices with others of higher energy class. This is accomplished by spending 'Wallet points' accumulated through the successful completion of tasks and missions appropriate for each level.

The next level is the 'Office' which unlocks after the user has managed to accumulate a certain number of points at previous levels. To reach the ultimate goal of net zero energy consumption buildings (nZEB), electricity microgeneration is enabled from this level on. The user first learns to optimize the electricity use and consumption of all his/her buildings, residential or professional, and then is allowed to use 'Wallet points' for the installation of electricity generation components. The concept of electricity production is a very important one in the game, since it allows the user to think of electricity as a resource and not simply as a costly comfort enabler. The user is also granted access to new educational material concerning electricity generation and storage devices, such as photovoltaics, wind turbines and batteries, as well as the relevant legal framework.

'My Home' is the last level where the user can a) simulate the electricity use of an actual installation, e.g. his/her house b) with the acquisition of appropriate hardware, monitor the electricity use of the actual installation and have full control of it, setting operating points and allowing remote on/off of appliances. At this last level, the user is given the opportunity to relate what he/she has learned to the real world.

"Wallet points" are earned when tasks and missions are accomplished, such as answering a set of questions, reading material, creating new content, inviting a friend, commenting on another user's actions etc. They are spent when higher energy class devices are acquired and installed and are lost when resources are managed poorly.

The idea of trade-offs involved in the use of various technologies underlies all actions in the game as it is important that the users learn to apply judgment and not simply follow trends or shy away from innovation.

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The increase or decrease of “Wallet points” activates the pleasure/pain dipole as the user is pleased to see his/her wallet points grow through successful missions or timely moves but experiences pain and frustration when points are lost; the user is then triggered to gather more wallet points by participating in new missions. The SMARTEGE leaderboard shows the user’s ranking which depends on points earned through user actions related to the optimum management of resources and electricity profile changes. Users are also awarded badges upon certain achievements.

In SMARTEGE all three FBM stimuli are used: a) Risk messages, warnings, award announcements are used as sparks; for example, a warning message is issued when the facility operated by the user has very high consumption at an unlikely time of day b) Facilitators are usually in the form of advice; for example, a message prompting the user to answer a quiz for point collection to be redeemed in appliance upgrading improving his/her consumption profile c) Signals are simple reminders or advice; for example, a message notifying the user to purchase a second PV panel.

Social acceptance / rejection is a powerful dipole in SMARTEGE linked to the use of social media. The user is given the opportunity to shape his/her profile / position in the ‘market’, to compare positions and actions with others, to view user profiles, rankings and achievements. Furthermore, the user can invite friends, form an identity and achieve a certain status in the SMARTEGE world.

5. FUTURE RESEARCH DIRECTIONS

In the future, the social dimension of the game will be upgraded to allow users to form alliances and compete by selling and buying electricity thus creating a virtual market regulated by the administrator. The application’s environment will be enriched with more building types with different energy profiles. The application will be tailored to specific learner’s needs, e.g. school building managers, public building users, etc. Based on the test phase results, anticipated early in 2016, future versions will also collect data and information for accurate user profiling in order to personalize the application’s content and thus enhance the behavior modification aspect of the application.

6. CONCLUSION

Well established models used in digital marketing and gaming are proposed to be used for the development of gamified applications for informal learning targeting technological literacy. Here they are applied to develop a mobile/tablet application for literacy in electrical engineering technology. When developing applications for adult learners one must keep in mind that their motivation stems for a variety of reasons and their engagement is linked to immediate, tangible results. Such an application must (Carr et al., 2014): a) offer feedback in a form similar to the student assessment while not snubbing the gaming practices: immediate, incremental, progressive and fun b) have a clear aim and not rely simply on the user’s desire for learning and investigation c) pertain to the user’s everyday life, experience, and culture d) offer levels in a form similar to creating a course while using gaming practices to engage the user, such as tasks and missions e) allow for design of own learning path and curve f) allow for social interaction.

So far the benefits and mechanics of gamification have been presented as a novel education tool with applications in informal learning towards technological literacy. As mentioned earlier, every technology has its limitations, trade-offs and risks. In this case, when designing such an educational application we should ask ourselves why is

gamification shaped in this particular way, which interests it serves, what are its long-term effects on mass education, should learning material be a product or part of the edutainment business. Finally, the ubiquitous nature of such applications encourages the spread of mistakes and erroneous information so careful control over content is needed.

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