The Internet of Things Considered in Context of the Classroom of the Future

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ABSTRACT

In this paper we advocate an approach that supplements current teaching, an approach which is supported by Aristotle's empirical view of the world where knowledge is gained through firsthand experience. This approach exploits certain properties of the Internet of Things, such as sensing the environment in which the learner is situated, and the ability to inform the learner about the environment. Taking Aristotle's view of the world as our departure point, we look at what the learning experience used to be like and compare that with what we perceive it to be now. We propose the incorporation of the Internet of Things to aid experiential learning, supported by scenarios where the Internet of Things has been integrated with a child's daily activities. Examples of both commercial products and research experiments are given to support the notion of integrating some aspects of learning with the Internet of Things.

Categories and Subject Descriptors

H.5 - INFORMATION INTERFACES AND PRESENTATION

General Terms

Internet of Things, Education, Classroom, Constructivism.

1. INTRODUCTION

The internet has affected the lives of almost everybody, either directly or indirectly. We have witnessed its emergence as a data distribution system, to its recent transformation to include social networking. A third major application of the venerable internet is now imminent; dubbed the Internet of Things. This emerging application of the internet enables geographically separated physical objects to sense the environment, run embedded software processes, act on the environment, and communicate with other physical objects and people using the internet as communication medium. We next briefly discuss divergent learning philosophies, of which one is core to our research.

Two great thinkers have influenced the way we approach teaching and learning: Plato and Aristotle. In Figure 1, Plato and Aristotle are depicted by Raphael as being at the School of Athens, circa 1510 [24]. They are depicted according to their central philosophies: Plato points upwards, indicating that the truth is found in ideas. He called this concept his "theory of forms". Plato's "theory of forms" is dominant in current school teaching. In contrast Raphael depicts Aristotle as gesturing to the ground, indicating that the truth is grounded in observation [12]. It is Aristotle's empiricism view of knowledge on which we base our argument in this paper.

Figure 1. Plato and Aristotle as depicted by Raphael.

While this empiricist view of knowledge is still valid today, our world-view has changed. Aristotle's world-view was superseded by the start of modern science as we know it, in what is commonly referred to as the Scientific Revolution of the 16th and 17th centuries, which was led by Copernicus, Kepler, Galileo and culminated in the work of Newton [1]. The all- encompassing explanatory scheme of Aristotle with its holistic and organismic view of the universe was replaced with a mechanistic model in which explanations were focused on isolated parts of reality. A prime example is the work of Galileo on the motion of bodies falling to earth where an aspect of the world is isolated and idealized (e.g. by ignoring wind resistance) and explained using the language of mathematics. Galileo's work is an example of the gradual building of scientific understanding on the basis of the accumulation of many of these types of investigations where aspects of reality are isolated, idealized, measured and described. In this learning process the collection and interpretation of data plays a key role which can be enhanced by the use of the internet.

We have structured the paper as follows: Section 2 provides a brief overview of the Internet of Things, and reflects our view on learning, past and present. In Section 3 we provide scenarios

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where the Internet of Things is integrated with learning. Section 4 takes a look at the feasibility of the scenario. Section 5 concludes.

2. BACKGROUND

2.1 The Internet of Things

The Internet of Things (IoT) is a relatively new research domain with the initial concepts having been formulated at the Massachusetts Institute of Technology (MIT) at ~1998 [2]. Research commenced during the same period [25]. The IoT concept can be distinguished from previous internet developments in that the main objective is for augmented objects to share information using the internet as the communication mechanism. This is the third major internet development. The first was the original internet aimed at making remote data available to humans. The second major development was that of social networking; geographically remote people can easily communicate. The IoT holds the promise of being a dynamic collection of many objects that sense and act upon the environment, gather data, do preliminary processing on the data, and share it with other devices also connected to the internet. The information shared in this fashion can optionally also be made available to people.

2.2 Learning in the Past

Throughout the ages the dominant approach to formal learning has been based on Plato's central philosophy. This philosophy posits that ultimate knowledge is gained through reasoning as opposed to our physical experiences [20]. Knowledge has thus traditionally been presented in the form of printed literature, supported by the knowledge of the teacher (also gained in a similar fashion). Freire calls the transfer of static ('fixed') content from teacher to learner in this fashion "banking" [15]. One problem with this learning approach is that the knowledge is not transmitted from the source to the learner without modification. Rather, the learner reconstructs the material in a way that makes sense to her [18]. Knowledge is thus modified with every transfer between source and human recipient. When knowledge is modified in this manner it is influenced by the recipient's view of the world which includes the recipient's life experiences, or lack thereof. Should the learner not have a life experience relating to the knowledge being transferred it stands the risk of being 'lost'. This deficiency in current learning methodologies is part of the reason we are advocating, as has been done by others, the inclusion of first-hand life experience as a supplemental learning methodology.

2.3 Current Reality

The current generation is accustomed to modern technology; including being connected via the cell phone and computer. Learners are also socially connected, using for example Facebook [23] and MXiT [4]. Little reading is done when compared to prior generations. Instant communication and gratification is expected by current learners. Children are expecting to be empowered to make decisions and have resources to set and achieve their own goals. Learners' thirst for knowledge can outstrip the ability of teachers to provide them with the means/knowledge. As adults we should ask whether it is moral to limit the learner's achievement because we cannot provide them access to domain experts. A possible solution to these challenges could be found in giving learners access to resources that will help satisfy their thirst for knowledge. What better way to satisfy that thirst than to make the tools and mechanisms readily available to them and let them gain the knowledge either individually or in a group of peers.

2.4 Constructivism

Constructivism is a theory that posits that people construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences [26]. When people encounter something new, they reconcile it with their previous ideas and experiences, in the process changing what they believe and creating their own new knowledge. In the classroom, constructivism usually means encouraging learners to use active techniques such as experiments and real world problem-solving to create more knowledge and then to reflect on and talk about what they are doing and how their understanding is changing.

Social constructivism views each learner as a unique individual with unique needs and backgrounds. It encourages the learner to arrive at his version of the truth, influenced by his background, culture or embedded worldview. Social constructivism emphasises the importance of the learner being actively involved in the learning process, as opposed to the responsibility resting with the instructor. This theory states that motivation for learning depends on a learner's confidence in his potential for learning. This belief emanates from first-hand experience in problem-solving. Through successful completion of challenging tasks, learners gain confidence and motivation to embark on complex challenges.

In constructivism, instructors adopt the role of facilitators and not teachers. A facilitator provides guidelines on how a learner should arrive at his own conclusions. In the 'traditional' learning environment the learner plays a passive role, while in constructivism the learner is actively involved. Learners with different skills and backgrounds collaborate during task execution and discussions to arrive at a shared understanding of a truth in a specific field. Constructivism theory posits that learners should be constantly challenged with tasks that refer to skills and knowledge beyond their current level of mastery. This is in line with Vygotsky's 'zone of proximal development' concept [16], which describes the 'distance' between a learner's current developmental level (as determined by independent problem-solving) and the level of potential development as determined through independent problem-solving activities. In this paper we base our epistemological stance on the constructivism theory.

3. LEARNING WHILE LIVING

Prior research has shown that young children thrive intellectually in environments where they are free to explore the world [6]. The experiential learning theory supports this research and states that ideas are continually shaped and reshaped as we experience life [15]. Experiential learning theory also accommodates the following three models of the experiential learning process: the Lewinian model of action research and laboratory training, Dewey's model of learning, and Piaget's model of learning and cognitive development [15].

3.1 The scenario

In the scenario which we describe in this paper, we consider a classroom that has expanded beyond the physical building to incorporate all aspects of daily life of the learner. We situate the scenario as follows: A young learner's typical weekday activities would be something along the following lines: wake up in the morning, prepare for school, travel to school, attend classes, have two breaks during school hours, travel back home from school, do school homework, spend time outdoors in unstructured play, have dinner, free time, prepare for bed, and finally go to bed. A number of learning opportunities outside the formal classroom present themselves in this scenario. When these learning opportunities are exploited we have what we call the 'Classroom of the Future'.

The concept of an "expanded" classroom appears to be feasible because the IoT, as we have discussed elsewhere in this paper, can sense the environment, process the data to produce information, and make the information available for mass consumption.

Research by others [27], similar to our own, address the notion of getting the youth away from the computer screen and out to the playground where increased physical activity has an added health benefit as compared to indoor activities limited to interactions with a computer. Yannakakis [27] posits that outdoor activities exist that provide stimulation which is similar to that provided when interacting with a computer, the children will tend to remain interested in physical outdoor activities. Similar to computer games, the Playware [17] [7] playground also adjusts the physical play according to the player's progress in order to keep her interested, and also keeps track of the individual players and their performance when interacting with the Playware devices in the playground.

In the world of self-discovery which we present here, these concepts are expanded further by considering the integration of various technologically-enabled devices that share information amongst themselves, and with people. Whereas the Playware research is focused primarily on the health of children, our work focuses on the learning opportunities presented by integrating IoT-technology with the child's world.

3.2 Movies distort life but also aid learning

Learning through life experience also has the added benefit of helping dismiss the often incorrect perception the public has of science and scientists. Van Riper [19] gives examples of such misconception in the form of effects often seen in movies. The so-called 'Hollywood-physics' does not adhere to the physics described by scientists. Examples of 'Hollywood-physics' include the sound that emanate from the space craft engines in the movie Star Wars. The sound would be plausible while the craft is within a planet's atmosphere, but the movie director of Star Wars decided that having a battle in space between adversaries with no explosions will simply not attract an audience. This assumption is of course true and other movies also make use of this scientifically-incorrect sound propagation model. This creates an incorrect perception of science amongst the novice, leading to difficulty at university when these preconceived ideas, influenced by Hollywood, have to be unlearned. We do, however, acknowledge that the movies can at times be of use in the learning process. Efthimiou [9][10] illustrates the exploitation (in a positive way) of movies used in the classroom by discussing pseudoscience in popular recent movies. Titles such as Aremageddon, Spiderman, and Batman are used as examples of how movies can be used as a tool when teaching science.

Movies and video games are great influencers of our youth and the incorrect physical models incorporated into some of these commercial works will probably have a detrimental effect on future scientists. It is, amongst others, a reason why the architects of the Classroom of the Future need to seriously consider the incorporation of everyday life experiences as a source of learning.

3.3 The IoT wrist watch

Another way our work differs from Playware [17] is the integration of various sensors embedded in various objects which together provide rich data on the environment in which the child finds herself. This is in contrast with the reported Playware concept where play apparatus operate independent of each other.

Figure 2 illustrates one possible implementation model of the IoT as it relates to learning. In this figure sensed information originating in the physical world is channeled to an IoT service, such as BeachComber [3]. BeachComber serves as an interface between the physical and virtual worlds, 'translating' communication protocols such as those used by Twitter [13] [14], FaceBook [23], WWW browsers, and MXit [4] to the Java Message Service (JMS) [22] as is used in some implementations of the virtual world. Through BeachComber, the sensed information is simultaneously persisted for later retrieval and distribution to other physical devices.

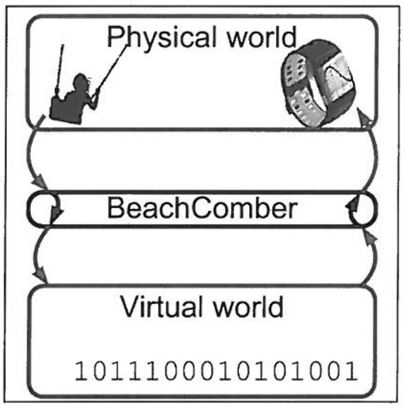

Figure 2. The data transition between the physical and virtual worlds.

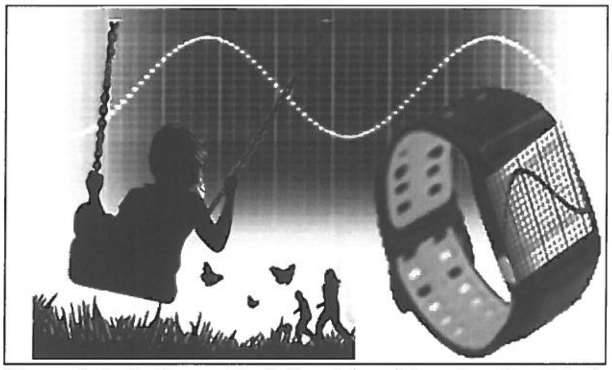

Figure 3. A display on the IoT wrist watch makes the virtual world visible.

A hypothetical example of a physical device that can connect to the internet and display data is what we call the IoT wrist watch (Figure 3, right). In the recent past we have witnessed a dramatic increase of functions incorporated into cellular phones. Not only has the size of this device reduced by leaps and bounds over the last decade, but so too have the functions embedded inside the phone increased in number. The current state-of-the-art is such that when we look for a replacement phone, we now take the original function of the device (making and receiving phone calls) as a given. Instead of enquiring about the incumbent device's telephone abilities, we are interested in its added functions such as its ability to connect to the internet and display complete movies. From this we can conclude that it is now undeniably possible to produce a consumer item such as the IoT wrist watch. We describe the IoT wrist watch next.

Let us for a moment contemplate the potential features of the IoT wrist watch: As a minimum, the IoT wrist watch will incorporate a cellular phone to make and receive calls. If the device is primarily targeted at young people, it would probably also incorporate an emergency mode. The watch can be placed in the emergency mode by pressing or twisting a specific area on the phone. While in the emergency mode, the phone will automatically open a voice channel to the emergency services.

However, the functionality of interest in this paper is the anticipated ability of the IoT wrist watch to connect to the internet and display large dynamic images. The wearer of the IoT wrist watch can select a data source from a list, and the data will be dynamically displayed on the watch face.

The next subsection describes four scenarios to illustrate how the IoT can be integrated with a learner's daily activities and consequently form part of the Classroom of the Future.

3.4 Learning in the playground

In Figure 3 we portray a hypothetical situation in the playground where the IoT wrist watch displays a graph which reflects the motion of the swing.

Consider how the following events unfold in our playground scenario (Figure 3): Our learner has chosen to view the real-time dynamic information on her graphic wrist display. As she starts to enjoy the swing, she notices that the *amplitude* of the swinging motion increases as she puts increases her effort. She also notices that the effort exerted affects the *period* of the motion, but that for small amplitude the period is almost unchanged. However, when her older brother and his friends also play on the swing, her observations remain the same. When the children move to an adjacent swing which has longer supporting chains, they notice that the period of the swinging motion is longer.

The learning in this scenario is three-fold: First, the period of the swinging motion is unaffected by the weight of the person. Second, the period of small swinging motions depend on the length of the supporting chains (Figure 4). Third, the amplitude of the motion is directly related to the energy she exerts.

3.5 Learning when travelling to school by car

Consider the scenario where our learner lives some distance from her school and relies on her parents to take her to school each weekday. Her parents take turns in driving her to school. Her father finds it more convenient to take the old road through the plantation fields on the outskirts of the town (Figure 5, left). This old road was constructed during the great depression of the 1900's and was not designed according to modern engineering principles. The road her mother takes is modern and is constructed according to modern engineering

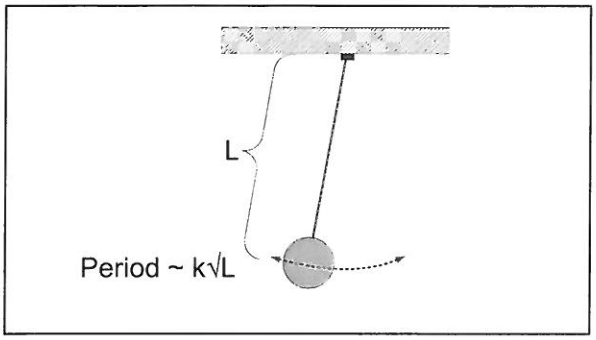

Figure 4. The period of a pendulum is related to its length.

principles (Figure 5, right). Her father does not travel this road because he does not think the toll fee charges along this route are reasonable. Her mother is however happy to pay for the comfort of driving on a modern road.

When taking the old road (Figure 5, left), our learner has notices that she tends to lean over to one side as the car travels through a sharp bend in the road. At times when the car travels exceptionally fast through the bend in the road, she has to take hold of the car door handle to stabilise herself. However, our learner does not notice these inconveniences when travelling with her mother along the modern road (Figure 5, right), no matter how fast the car was going.

It is the perceived difference in comfort when driving on the two roads that prompts our learner to investigate the reasons for this further. She conducts her investigation with the aid of her IoT wrist watch. This she does by accessing data from the car sensors, and plotting this data on the wrist watch display as the car moves through the bends on the alternative roads. From her analysis, it appears that the car travelling along the old road experiences large forces at right angles to the direction of travel. These forces, she concludes, are the reason she either leans to one side when moving through the bend in the road, or has to hold onto the door handle when travelling through the bend at high speed. In contrast, no such forces are evident when travelling along the modern road. In reality, these forces are aligned with her body, making the experience much more pleasant than is the case for the bends in the old road.

By conducting this experiment with the aid of her IoT wrist watch, our learner is able to come to two conclusions: First, the speed at which the car travels through the bend in the old road has a direct correlation with the sideways force which she experiences. Second, when travelling along the modern road, it does not matter at what speed the car travels through a bend in the road. The experience is always acceptable. After careful consideration, our learner deduces that the banking of the road surface is the reason for the difference in the lateral forces experienced along the two roads.

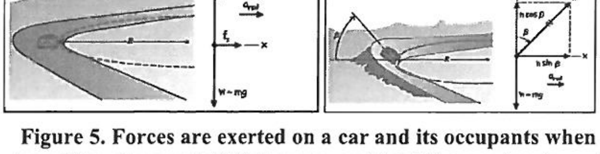

Figure 5. Forces are exerted on a car and its occupants when travelling along a (left) flat curve, and (right) an embankment [28].

3.6 Learning when preparing a meal

Cooking is a combination of science and art. The science is in understanding the effect of ingredient quantities and their ratios when preparing a meal. Art (as considered in the sense of talent or intuition) also plays a role when preparing a meal because science is only a model for observed phenomenon: A model developed by a scientist is never complete and evolves as new insights are gained about the phenomenon being modelled. It is for this reason that we can state that cooking is a combination of science and art.

The scenario which we now consider has the learner boiling potatoes in water. Boiling the potatoes will soften them so that they can either be consumed as-is, or mashed.

Our learner notices that it seems to take less time to get the water to boiling point at high altitude (her current location) than when she was on holiday at the sea coast. Being a person with an enquiring mind, she decides to conduct a few experiments to confirm her suspicion. She uses her IoT wrist watch to access data related to the kitchen stove's energy consumption. Now she can vary the heat setting on the stove and see the associated variation in the energy consumption as displayed in her IoT wrist watch. Our learner now conducts an experiment to determine whether more energy is required to get the water to a boiling point quicker, as opposed to using a low heat setting and waiting for a longer time.

By using the data made available through the IoT, our learner has easy access to accurate figures which enabled her to conduct simple experiments relating to energy conversion.

3.7 Learning when visiting the shopping mall

In her free time, our learner sometimes visits the shopping mall with her friends to enjoy an ice cream. With its many levels, the children sometimes make use of the elevator to move from the entrance level to the level where the food court and their favourite ice cream parlour is located.

As the children select the destination on the elevator control panel and the elevator sets into motion (Figure 6), the children notice a gradual increase in what they perceive to be their body weight. This is not the first time that our learner has experiences this feeling, but now that she has her own IoT wrist watch, she decides to investigate the experience. Our learner adjusts her IoT wrist watch to reveal a list of IoT-augmented objects in the mall. From this list she selects the elevator they are travelling in. Her IoT wrist watch immediately displays information on the movement of the elevator. The data displayed on the watch is updated in real time and includes the elevator' vertical position, the speed at which it is moving, and its acceleration. Our learner then discovers a correlation between the 'changes in weight' she experiences, and the acceleration values displayed on her IoT watch.

A few years later when our learner attends her Physics 101, she is formally introduced to the concept of acceleration and the effect it has on the weight of an object. This is when she recalls her experience in the shopping mall elevator a few years prior. Our learner has now made a cognitive association between her real life experience and Newton's third law of motion [8], which in the vernacular states that "every action has an equal and opposite reaction".

3.8 Life is a preparation for university

These observations made by the child herself of the physical happenings around her, as she is involved in her daily activities, will later stand her in good stead when the mathematic equation of a swinging pendulum [28] (Figure 4), the forces on a car as it moves through an embankment in the road (Figure 5), the latent energy of water, and the relationship between weight and mass (Figure 6) are formally introduced in her first year physics class at the local university.

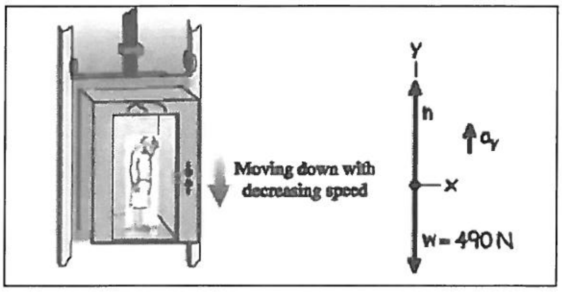

Figure 6. Perceived weight varies in a moving elevator [28].

3.9 What makes these scenarios possible?

The reader may well ask how the above scenarios could be realised. The answer to this question is not complicated and the realization of these scenarios is not too far in the future either. In this subsection we consider each of the scenarios and the technology that could enable them.

3.9.1 Playground swing

In this scenario the swing apparatus has been augmented with sensors for two reasons: First, to support business and second, to support learning. It is important to consider the business perspective in order to have an IoT learning environment which is financially sustainable.

From a business perspective the sensors serve as a mechanism to inform the local municipality of usage patterns in the play park, and as an aid to the efficient scheduling of play park apparatus maintenance.

From a learning perspective, live data is accessible in real time, providing a learner (equipped with suitable technology such as the IoT wrist watch) to make a cognitive link between the physical act of swinging and the sensor data.

3.9.2 Travelling by car

Motorcars seem to constantly increase in price, but this is probably because of their improved features such as better safety for the driver and passengers. Safety is assured by the sensors that continuously monitor the vehicle's acceleration, speed, fuel consumption and a myriad of other subsystems contained in the vehicle. Data from the sensors are interpreted and decisions made. Interpretation is mostly done by the many on-vehicle processors, but we envisage that the data may in the near future also be sent to an off-vehicle system where data from multiple vehicles on the road are constantly monitored.

Also added to the modern vehicle is positioning sensing and reporting systems. The purpose of these systems is twofold: first, navigation systems assist the driver in driving to a pre-determined destination. Second, the recovery of the vehicle in the event of theft is made easier.

In the scenario where our learner monitors the affect road construction has on the acceleration forces she experiences, data from the multiple sensors incorporated into the car are constantly sent to a central system and relayed back to the IoT wrist watch of our learner.

By using this information, our learner is able to correlate her physical experience with data derived from the car sensors.

3.9.3 Preparing a meal
The home kitchen can be a dangerous place. This is where electricity, water, gas, and various volatile and flammable chemicals are located in a single room and in close proximity.

We anticipate that in the near future various sensors will be incorporated into the kitchen for two reasons. First, some sensors will be used to monitor the kitchen for hazardous events, such as fire. The second reason we anticipate that sensors will be incorporated in the kitchen is to monitor the use of energy sources. These sources can be either electrical or gaseous in nature.

The increase in energy consumption is a global problem, with many local authorities requiring proof that new developments will limit their energy consumption to a reasonable level. It is therefore in support of both the consumer and the local authority that we anticipate the installation of the sensors, and the associated distribution of energy consumption figures to both the rates-and-taxes payer as well as the local authority.

The rates and taxes payer is interested in the energy consumption because it affects his pocket directly. In contrast, the local authority's interest is mostly for planning purposes when purchasing new infrastructure.

It is the data that is made available to the rates-and-taxes payer which the girl can access using her IoT wrist watch.

3.9.4 Going to the mall
A mall is a large structure with multiple mechanical devices that need regular maintenance and monitoring for malfunction. In the scenario where the group of girls visit the mall, they make use of one of the most complicated devices in the mall: the elevator. Not only does the combination of mechanics and electronic circuitry have to ensure that the passengers reach the correct floor, but the safe operation of the elevator is vital. It is because of the latter requirement that a multitude of sensors are integrated with modern elevator installations. These sensors are continuously monitored by custom-developed computing devices. When a possible malfunction is detected, the elevator is automatically shut down to prevent human injury.

With multiple elevator installations in a single large mall, it becomes feasible to feed data from the installed sensors to a central automated monitoring system where predictions may be made on the current condition of each elevator. Maintenance schedules can also be adjusted from this central system because real-time data on each elevator is available. Communication between the elevator sensors and the automated central monitoring system can be cost effective if it happens over the internet. The combination of sensors feeding data to a central system over the internet is an example of the Internet of Things. Some of the data that flows along the IoT can also be made available for public consumption. In the elevator scenario, the girl has decided to access data from the sensors which are attached to the elevator and display it on her IoT wrist watch.

By using this information, our learner is able to correlate the acceleration of the elevator with her subjective 'change in weight'.

The next section briefly discusses research projects and commercial product that illustrate how close we are in realizing the Classroom of the Future as proposed in this paper.

4. ALMOST a REALITY
The concepts presented in this paper are not far-fetched. Development has been ongoing for decades on devices and systems that monitor the environment and the user's actions and make the data available in real time. What has changed over the years is the size and complexity of these monitoring systems. Continuous development of new materials now makes it possible to construct compact sensing- and computational technologies which can be incorporated into everyday objects in a unobtrusive way. Two such systems are described next. The first is a research project, and the second is available as a commercial product.

4.1 CabBoots
CabBoots (Figure 5, left) is a research project which incorporates shoes fitted with position sensors and actuators. When in use, the sensors communicate with a computing device where the deviation between the current- and desired shoe position is calculated. The deviation is sent to the shoes as control signals. These control signals are interpreted by the embedded circuitry which instructs embedded actuators accordingly. The shape of the shoe soles change in such a way as to guide the wearer along a virtual path [11].

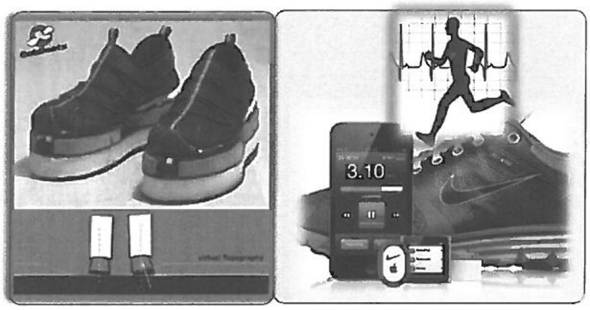

Figure 5. CabBoots (left) and Nike+ (right).

4.2 Nike+
Nike+ (Figure 5, right) is a commercial embedded product that collects information from running shoes while the wearer jogs. This information is made available to the user in real time via an iPod or iPhone [21].

5. CONCLUSION
In this paper we have presented scenarios where a child learns from real-life experiences. This learning compliments current formal learning. Making use of the numerous freely available information sources which we anticipate will be distributed through the Internet of Things, a child can gain first-hand exposure to the world of science.

Experiencing and taking note of the forces and other phenomenon in daily life can shape the learner's preconceptions [5] of mechanics as she progresses to tertiary education. With an increased and accurate understanding of the world around her, the learner has a greater change to be successful at her engineering degree.

As discussed in the introduction, this approach is part of a gradual building of scientific understanding on the basis of the accumulation of such types of investigations in which aspects of reality are isolated, idealized, measured and, ultimately, described mathematically. A bridge is formed between experiments and theory development.

6. ACKNOWLEDGMENTS

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