Opinions on the Internet of Things in the Industrial Design Curriculum

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Abstract

The aim of this work investigated whether there is a need to incorporate the Internet of Things (IoT) into the Industrial Design curriculum. Initial research comprised a literature review into the origins, growth, challenges and enabling technologies for the IoT. Furthermore, literature around IoT within the current curriculum and for industrial designers and graduates was explored. Whilst this work considers the possibilities and capabilities through various visions and methods of application, the fundamentals of the technical side are considered in order to understand these possibilities for the IoT as a subject.
A mixed-method approach was designed which used a structured questionnaire survey for industrial design students and interviews with design lecturers. The results revealed a majority agreement into the need and interest for Industrial Design Curriculum to incorporate IoT subject matter, however, with much debate and discussion into how this may be envisioned. The work concludes with implementation through a mixed approach to teaching microcontroller design applications combined with project-led problem based learning allowing students to combine their design skills into product concepts and prototypes in order to realise and develop the future Internet of Things.

Key words

Internet of Things, Industrial Design, Design Education, Smart Objects.

1 INTRODUCTION

The Internet of Things (IoT) is a relatively new concept which has stimulated much discussion over the last decade into its meaning, scope and more importantly the barriers to its widespread adoption. As the concept of IoT has become more popular then there may be justification for teaching it in higher education. The purpose of this research was to explore the possibilities of incorporating methods of the application of the IoT into the industrial design curriculum. The main objective of the work was to identify whether there is a need to incorporate the Internet of Things. As such, this work sought to explore the understanding, concepts and driving factors of the IoT and how it may offer opportunities and applications for industrial design students. The underlying research questions comprised:

- Does the IoT offer employment/career opportunities within Industrial Design?
- Should we address the IoT in our technology modules within Industrial Design?
- What platforms for IoT development should be used in teaching?

These research questions were addressed through a combination of research approaches, primarily, through an extant review of literature into the IoT which examined growth and scope, goals, visions and applications and enabling technologies driving this growth. This work then explored how the IoT is currently understood in design education and opportunities that IoT may have for design graduates. Further research has been undertaken in the form of primary data from both questionnaires from industrial design students and interviews with industrial design lecturers which was analysed and discussed.

2 LITERATURE REVIEW

2.1 The Internet of Things (IoT)

The Internet of Things (IoT), also referred to as physical or ubiquitous computing (McEwen & Cassimally, 2014), is a subject with no agreed underlying definition as the possible applications and visions are yet to be entirely explored. In order to understand the concept, one may

Figure 1: Mimo Baby Monitor (Source: Mimo, 2015)

Figure 2: Egg Minder (Source: Quirky, 2015)

analyse the phrase, firstly determining the definition of 'The Internet' as 'the single worldwide computer network that interconnects other computer networks on which end-user services are located, enabling data and other information to be exchanged'. The internet of 'things' sets to expand this definition to a network of actual connected physical 'things' or objects rather than singular computers, that collect and exchange unique data information about environmental surroundings using embedded technology. McEwen and Cassimally (2014) summarise this as: 'Physical Object + Controller, Sensor and Actuators + Internet = Internet of Things'. These 'things' can be considered as any consumer product; from baby monitors to egg trays, as shown in Figures 1 and 2, and anything in between. These may be considered metaphorically as 'enchanted objects', where objects can have almost hidden and magical capabilities taken from science fiction. However, more technically, IoT can be described as uniquely addressable objects connected using standard communication protocols (INFSO , 2008).

2.2 Origins, Growth and Scope

Although the now commonly used term 'The Internet of Things' originates from Kevin Aston in 1999 after experiments at MIT's Auto-ID Centre in the fields of networking radio frequency identification (Farooq, Waseem et al., 2015), the initial vision is widely believed to have been from Weiser (1991) where he was the first to raise the issues of common interfaces of computers, such as keyboards, in daily life. A visionary goal was proposed of making the computer disappear by 'weaving into the fabric of everyday life until they are indistinguishable from it' (Weiser, 1991). This is a vision where computing is ubiquitous. Arguably, the actual 'birth' of IoT can be recently traced back to 2008/2009, as shown in Figure 3, where for the first time the number of connected objects exceeded the number of people connected to the internet (Evans, 2011).

Just as the internet has transformed the way in which we live and communicate and with around two billion people connected to the internet worldwide today (Miorandi et al., 2012), the IoT is predicted to be the next evolution. This emergence is predicted by Gartner's IT Hype Cycle, as shown in Figure 4 which forecasts the IoT to enter the market within the next 5 – 10 years, using an S-curve of adoption of technology (Atzori et al., 2010).

In addition, in 1966, Karl Steinbuch projected 'In a few decades time, computers will be interwoven into almost every industrial product' (Mattern and Floerkemeier, 2010). This is not yet the case, however, further research from Gartner predicts that in 2020, IoT products and services will generate incremental revenue exceeding $300 billion

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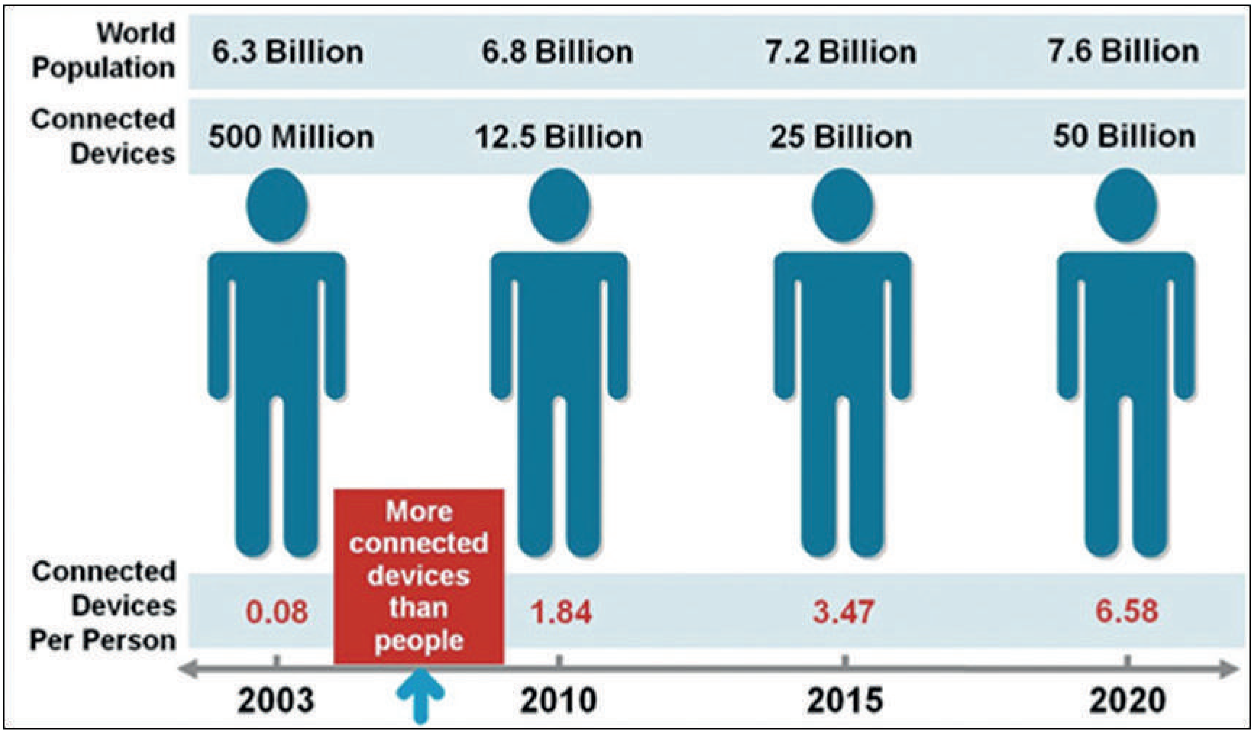

Figure 3: Growth in number of connected devices. (Source: Evans, 2011)

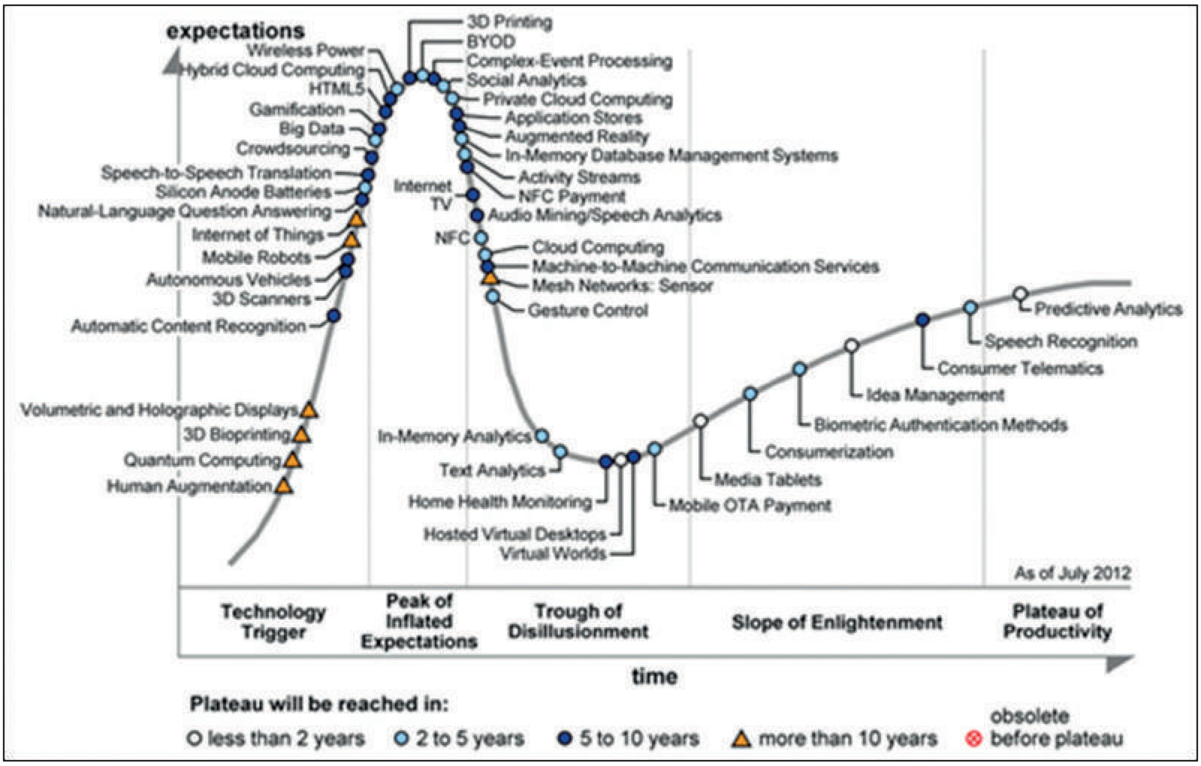

Figure 4: I.T. Hype Cycle (Source: Gartner Inc., 2012)

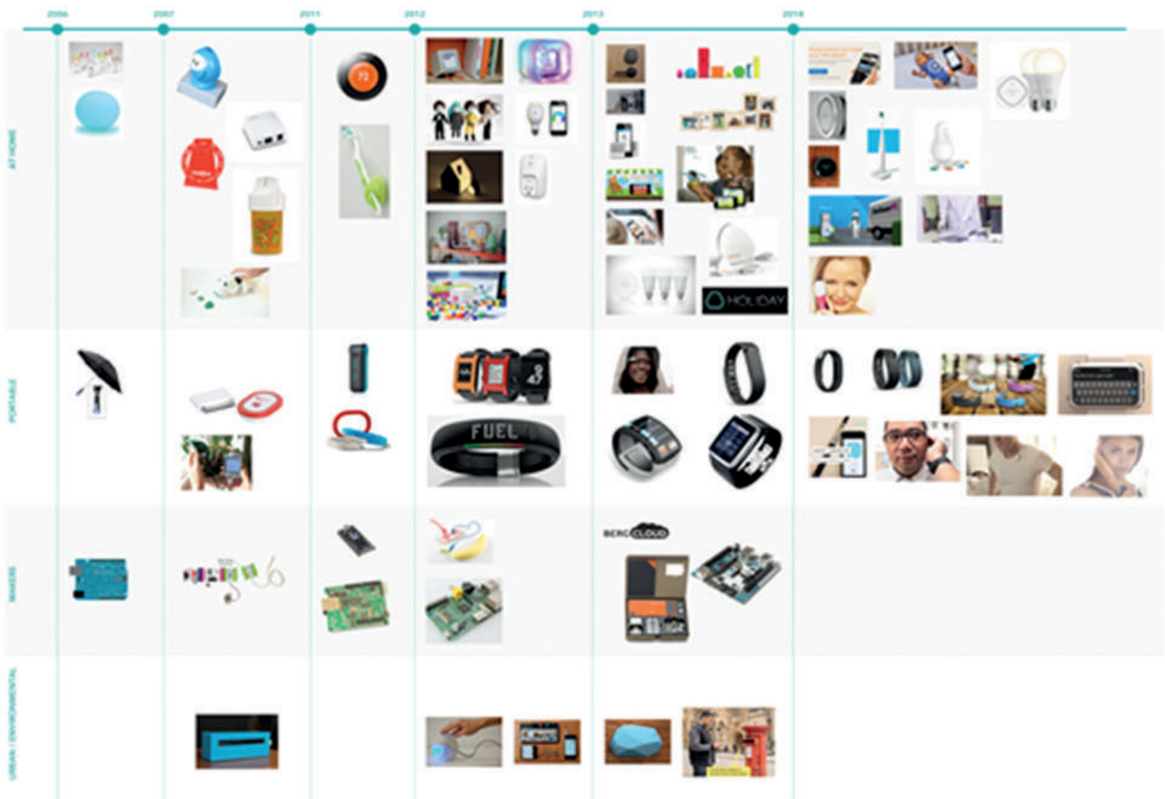

Figure 5: IoT market from 2006 until the present (Source: Deschamps-Sonsino and Beart, 2014)

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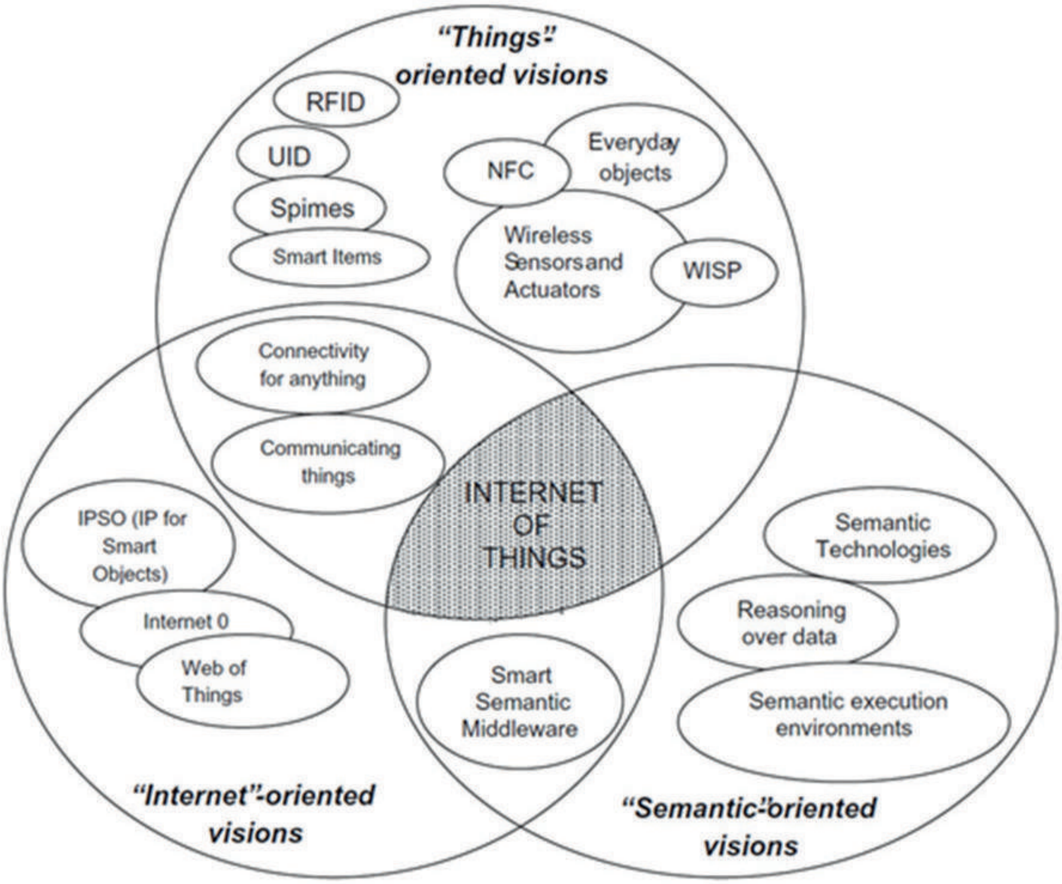

Figure 6: IoT paradigm as a result of the convergence of different visions (Source: Atzori et al., 2010)

with 5 billion devices connected to this system of systems and communicating with each other (Middleton et al., 2013) whereas communications company Cisco believes it to be closer to fifty billion devices (Evans, 2011). These figures may seem difficult to achieve in the next five years at the current state of the concept yet, the IoT revenue of China as of 2010 was $30 billion (Business Wire, 2011). Therefore, current estimates may be undervalued. Similarly, as only one percent of 'things' that can be connected are connected, it is estimated that this is relatively insignificant within the overall vision that an unlimited number of products will be able to be connected in the future (Deschamps-Sonsino and Beart, 2014).

Nevertheless, it is clear that the topic is becoming one of the most current new trends in the technology world and was the focus of the Consumer Electronics Show in 2014. Although growth has been relatively slow, there has been an emergence of IoT products released to into the market. Figure 5 demonstrates this expansion by tracking the IoT market from 2006 until the present, where the products displayed range from consumer electronics to specific microprocessors over various different market environments. There is an exponential growth as more new, popular products being realised each year. The website www.iotlist.com identifies these IoT products as they are released into the market. There is no question that there is an emerging vision however, questions remain regarding who will be leading the development and in what ways will it achieve global success.

2.3 Goals, Applications and Visions

Developments allow communication devices to be made smaller and cheaper, enabling the production of smart objects that act as building blocks into creating an Internet of Things system in the future. These technologies allow for unlimited possibilities of applications within the real world to achieve the goal of connectivity 'anytime, anyplace, with anything and anyone ideally using any path/network and service' (Vermesan and Friess, 2013). The development of these applications is one of the most important engines for public acceptance of the IoT (Coetzee and Eksteen, 2011). Within these countless areas of applications, there are consequently a matching number of visions for IoT. Nevertheless, as the concept is still young, the majority remain only as visions; posing much

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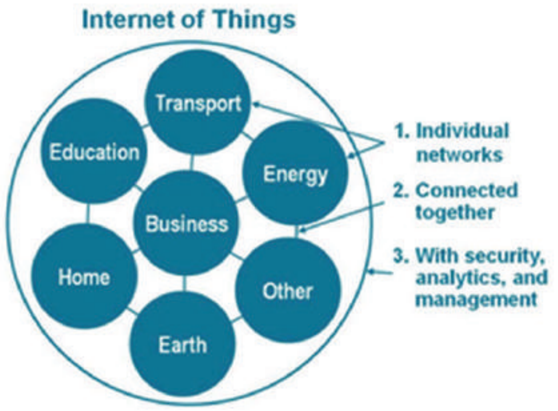

Figure 7. IoT: Network of networks (Source: Cisco IBSG, 2011)

discussion into what the future will be. Similarly, as a wide scope of applications can be imagined, these predicted visions will vary dramatically from different experts working in different fields.

Miorandi et al. (2012) believe that the IoT will be built upon three primary pillars for objects in order to be able to; be identifiable, communicate; and interact. Atzori et al. (2010) expand on these paradigms by recognising that IoT will be made up of more than simply 'things' equipped with RFID tags, but will converge internet-orientated (middleware), things-orientated (sensors) and semantic-orientated visons (knowledge) (Gubbi, et al.,2013) which is represented in figure 6.

Researchers at Cisco Systems identified the current attempt at the IoT as being a 'loose collection of disparate, purpose-built networks' as products (such as cars) consist of various networks to control various aspects (Evans, 2011). However, although these networks make the product 'smart', they are not connected to a bigger 'internet of things'. Cisco envisions the future evolution as a 'network of networks', where all sectors and the products within are connected and communicating together as shown in figure 7.

In the context of these collective visions in mind, IERC (2011) identifies eight main smart sector categories for the future as shown in Figure 8. While these sectors spark excitement for current and future generations, they may still be clouded, as Vermesan and Friess (2013) describe it, as 'impossible' to envision all potential applications due to rapidly changing technologies and user needs.

Figure 8: IoT Applications (Source: IERC, 2011)

2.4 Challenges and Threats
The predicted applications of the IoT will provide many benefits globally to consumers and companies alike. However, these pose challenges and threats which need to be resolved through further research before IoT can become a reality. Visions consist of data running on hardware which is not always directly interacted by the end-user and, therefore, an updated policy is needed. Regarding research for connected objects, two central challenges can be identified:

Identification: Each object in the IoT must be uniquely identifiable by either physically tagging through the use of RFIDs/QR codes, or providing each object with its own description and wireless communication (Miorandi, et al., 2012).

Sensing/Actuation: Each object must be able to connect to the physical environment either passively or actively, meaning that objects can embed the functionality to sense and act on different environments instead of being built for solely one task (Miorandi, et al., 2012). Additionally, Gubbi et al. (2013) identify other challenges, such as architecture of the IoT, protocols, data analytics and quality of service. With such a wide scope, these challenges bring forward many risks. In particular, trust, privacy and security are serious concerns that must be addressed (Babar, 2015). These become more challenging to achieve and control in terms of the expanded deployment and mobility of 'things', additionally with often low complexity within the cloud (Sundmaeker, et al., 2010).

Collectively, these security concerns are some of the main causes halting development in the public sector as there is limited public confidence (Atzori, et al., 2010). Additionally, they claim that within these, the main concerns are authentication and data integrity across the network infrastructure, where the IoT must especially provide unique identity authentication mechanisms and confidentially of the data (Farooq, et al., 2015), because applications will expand into the physical realm (Miorandi, et al., 2012). Therefore, as IoT expands into further areas, researchers and scientists are focussing on testing and solving these challenges. To this end, a number of frameworks have already been proposed (Miorandi, et al., 2012).

2.5 Enabling and Driving Technologies
The advancements in microelectronics driving IoT can be explained using Moore's Law which states 'The number of transistors incorporated in a chip will approximately double every 24 months' (Moore, 2006). This allows the increase of processing power with a corresponding cost decrease (McEwen and Cassimally, 2014), subsequently allowing exponential growth of IoT through overall reduction in terms of size, weight and energy consumption for microelectronics (Atzori, et al., 2010). The two central challenges of identification and sensing/actuation can be addressed by various developing microelectronic technologies that are driving the IoT. For identification technology, RFID systems are key, consisting of four main components: a microchip antenna to allow communication from the object; a tag reader; middleware that transfers the data; and a specific transponder 'tag' (Chaouchi, 2010). This RFID system combination enables objects to be monitored in real time from distance across all systems, allowing a wider range of application scenarios to map out the virtual world from the real (Atzori, et al., 2010). Nevertheless, developments in the technologies in terms of miniaturisation and power supply have brought on a

Passive RFID	– No need for embedded power – Tracking inventory – Unique identification number – More publicized (Wal-Mart, Metro, Department of Defense, etc.) – *Sensitive to interference* (metal, noise, etc.)
Semi-passive RFID	– Powers the microchip of the tag – Less sensitive to interference than passive tag (metal)
Active RFID	– Embedded power: communicate over greater distance – Unique identifier – Other devices (e.g. sensor) – Better than passive tags *in the presence of metal*
Semi-active RFID	– Power the transmitter part – Better than passive and semi-passive in a *noisy environment*

Table 1: A comparison levels of technology of RFID

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number of different types of 'tags' that can be used for identification in different applications. These are compared in Table 1. However, non-established global standards and disadvantages, such as reader collision from overlapping signals, currently act as problematic barriers to overcome (Vongsingthong and Smanchat, 2014). Additionally, a wide range of electronic sensors enable actuation depending on purpose, for example, chemical sensors are used to measure humidity, ion or gas concentration. However, to be applied to a wide range of objects, constraints, such as power, memory and storage, are currently limiting developers in which scientists must solve (Chaouchi, 2010).

2.6 Programmable Technology

Advances in programmable technology allow anyone with even limited knowledge of programming/coding to be able to program products to become smart connected devices through the use of embedded computers (Freescale and Emerging Technologies, ARM., 2014). Popular current platforms include Arduino, Raspberry Pi and Beaglebone: all boasting improved functionality in terms of processor speed, RAM, networking, inputs/outputs, power consumption and physical size, at competitive prices. With numerous factors taken into account, it is difficult to deduce a single suitable IoT platform as it is dependent on the individual's application needs and limitations. In terms of connectivity, Raspberry Pi offers wireless and interface display capabilities; acting as a Linux computer at a faction of the price, enabling easier, more powerful IoT solutions (Allan, 2013).

2.7 IoT for Industrial Designers

As we previously explored, advances in embedded microelectronics give scope to a seemingly endless number of applications over many different disciplines, in particular, consumer products. Subsequently, the form and function of products will not have to change so dramatically as once before (McEwen and Cassimally, 2014), enabling familiar original products to be transformed into devices with added capabilities, whether hidden or not. This allows consumers to interact with their products similarly in that they would usually. Obviously, this is a very exciting concept for industrial designers; exposing opportunities of new product concepts, families and companies that can claim incredible, increased functionality than ever before. However, there is currently limited input from designers within the realisation of IoT.

McEwen and Cassimally (2014) proclaim that in terms of design of objects in IoT 'although the physical design of your connected device may be less important, the extra functionality regarding how it will interact is something you should consider'. They continue by reminding that industrial design is not just involved with the form and beauty of a product, but with its functionality and interaction, and argue that 'if the internet of things is to succeed in reaching mass appeal, the lack of design is something we need to change'. Deschamps-Sonsino and Beart (2014) attempt to connect and visualise the key roles in making the 'things' in IoT and show the role of the designer as being one of the most impacting, supporting previous theories.

2.8 IoT in the UK Design University Education System

With excellent facilities and clever, young facilitators, design schools could play an important role, an Internet search of 'Industrial Design University Courses UK' reveals a total of 101 different university courses available to students. However, of all of these syllabuses, not one currently describes teaching applications of the IoT. Therefore, there may be a need for the syllabus to incorporate emerging topics, such as IoT, in order to not only attract new students to the course both domestically and internationally, but to maintain a competitive rank.

Similar situations have influenced the design curriculum in the past. For example, just as sustainability was realised, CAD systems developed and products contained interactive screens; design schools globally recognised the need to update courses to cater for these emerging real world applications, resulting in sustainability, CAD and interaction becoming common and key to designers. Similarly, Professor Simon Peyton-Jones states 'Children are taught physics and biology because we live in a physical and biological world. We now live in a digital world and children should be taught how it works' (Callaghan, 2012). The exploration through education and information are key aspects for the future success, where education of use and benefits of IoT must be carried out (INFSO , 2008). This may be through direct application from product designers, however; Mattern and Floerkemeier (2010) believe it will take more than 'everyday objects equipped with microelectronics that can cooperate with each other' (Mattern and Floerkemeier, 2010). This poses a challenging task for teachers and students alike to realise in practice.

Callaghan (2012) explains that a major problem facing teachers for IoT courses is managing open creativity that is enabled with the combination of software and hardware, specifically within tight session time const. Additionally, the possibility for limited concentration and effectiveness for students exists if pre-built systems are attempted to be used. On the other hand, system level solutions often only enable a single application or are too simple to enable an accurate product development experience for educational purposes (Wang, et al., 2011). Although microprocessors

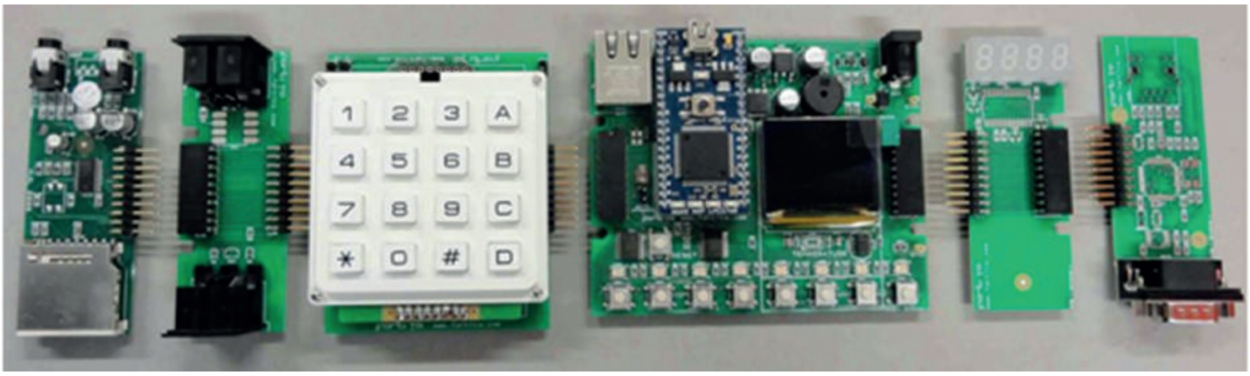

Figure 9: Buzz-Boarding (Source: Callaghan, 2012)

are taught in industrial design courses at university level it has yet to be applied to practise actual IoT applications, but rather, simple, unconnected electronics. Callaghan (2012) 'Buzz-Boarding' as a method of efficient experimentation for IoT, where the process is 'illustrative' rather than 'exhaustive'. This consists of students of using a standardised toolkit of programmable hardware boards, shown in Figure 9, with simple C and C++ software through simple applications to learn industry standards.

Interestingly, this technology is expanding. As of this year, IBM and ARM teamed up and have recently released the 'mBed for IoT', which can be described as an IoT starter kit that enables wireless connectivity with minimal coding ability through a drag and drop interface and running on IBM's NodeRed tool and Bluemix in the cloud (Scroxton, 2015). This has the potential to expand and enhance student involvement through a more simple system although it will assuredly need to be tested for application in practice for its usability and capabilities before implementation.

2.9 The Internet of Things for Graduate Designers

The IoT is predicted to develop in many sectors relating to the design world in the near future. New opportunities will arise as markets and companies transform, and it is believed that students should be trained for this wider spectrum of skills. This change can already been seen across the UK as large corporate companies such as Cisco, IBM and Intel recognise the potential for connected products. However, there are an increasing number SMEs and start-ups experimenting within these early stages using crowd-funding to help source and commercialize new connected products (Deschamps-Sonsino & Beart, 2014), in which as many as thirty exist across the UK. Internationally, numerous SMEs, having started as initial concepts having now developed into multi-million pound companies whose successes have been implemented into larger corporations. Examples include Nest, the connected home thermostat bought by Google, and Smart Things, a network of app-controlled home devices bought by Samsung. These new opportunities pose an exciting and broader future career for students currently enrolled at universities. The 'Internet of Things' is a young concept yet it exists in the interest for markets and prospective applications and visions for the future. However, in order to gain global success and adoption, the concept must be understood, researched and developed. In particular, numerous challenges and threats must be overcome, including implementation across different fields. Advances in technology are currently fuelling development to realise these visions, which in particular, microprocessors now enable IoT projects to be undertaken by a wider range of standpoints. This exposes an exciting interest and prospect for industrial designers, potentially still in training. However, research suggests that, currently, university design courses in the UK are not preparing students for this seemingly inevitable model.

3 RESEARCH METHODOLOGY

3.1 Research Approach

In order to explore this research topic, further information was required to support the secondary research. Therefore, primary research was conducted in which it is important to understand and acknowledge all aspects of research and its interpretation regarding theoretical approaches; categorised by two paradigm perceptions within the scientific community:

3.2 Mixed Methodology

For both quantitative and qualitative approaches, there exists a wide range of possible research methods. As the research requires data collected from both, it was appropriate to use a mixed methods approach. For quantitate data collection, the environment of the study was set to the Design School student population. With a large number of potential participants, it is important to use sampling accurately as a subset to represent the larger population. Contrastingly, for qualitative research collection, purposive sampling was used as a more exploratory sample; individuals were chosen specifically based on their known attributes in order to gain focused and relevant knowledge on the research topic. As this sample is based on a small population, it can be argued that the data is representative however, as the nature of the qualitative data is more subjective, it can also be argued that the data is based on opinions of individuals instead of the population.

3.3 Questionnaire Surveys

Questionnaires were completed by industrial design students in order to collect quantitative data regarding their views on the current curriculum regarding technology experimentation and their interest into the field of IoT. A random, sample of 62 participants from various years and courses were collected in order to represent the views of all combined years and courses. In order to achieve the random sample with efficiency and accuracy, an online survey software was used as a simple platform where the web link was posted in online social groups containing what can be concluded as the majority of members of the school population. The advantages of this method were that is enabled accessibility from anywhere, ease in arrangement and collection of results and provided accuracy through standardised questions online between all participants. However, disadvantages include information potentially lacking validity by containing a level of researcher imposition, although this was minimised by good research practice by allowing a wide range of answers and various revised questionnaire versions.

3.4 Interviews

Qualitative data was collected through a series of short, semi-structured interviews to a selection of relevant members of academic teaching staff from the design school. Interviews, with consent, were digitally recorded in order to refer to in detail at a later stage. Semi-structured interviews offered structured issues to be included and as the research questions for this study are relatively specific, this method was ideal to allow in-depth opinions and flexibility from interviewees. Interviews were beneficial in terms of collecting qualitative data over other methods; allowing insights to be gathered from the depth of information and improved validity of data through the direct, face-to-face contact. Nonetheless, it can also be argued that validity and reliability of interviews, in particular semi-structured, can be flawed as they can lack consistency and are only based on 'what people say, not actually do'.

Due to the mixed methods approach used, it was important to use a suitable analysis method and combine both quantitative and qualitative data for interpretation.
To combine these data sets of mixed methods, a concurrent triangulation design was most suitable as it allows methods to be collected separately with equal priority, resulting in an integration of both data-sets being able to support each other during the interpretation phase. Separately, the questionnaire survey data was collected and explored using a series of statistical, graphical figures, allowing ease of interpretation and comparison of different variables. However, interview data was noted through transcripts for direct interpretation and therefore, not included in the analysis section, only in the discussion.

4 ANALYSIS

4.1 Analysis of Quantitative Questionnaire Data

4.1.1 Population sample and course spread

Of the 553 students currently studying at the design school for the 2014-2015 academic year, 62 students in total competed the questionnaire. Of this population sample, there was a fairly even spread across all year groups, as shown in Figure 10. However, a clear majority existed in regards course: Industrial Design (75%), as opposed to Product Design (19%), Design Ergonomics (3%) and Human Centred Design (1%).

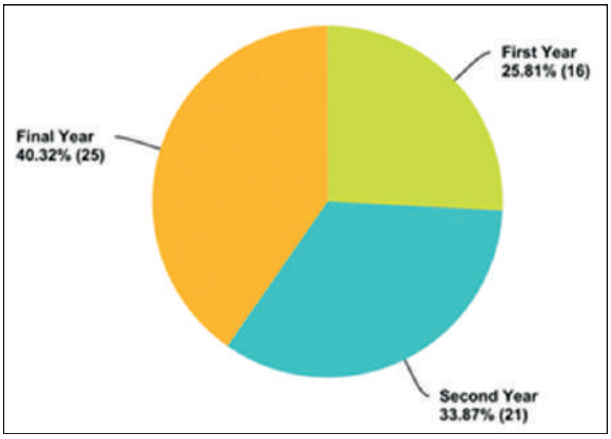

Figure 10: Design school stages

4.1.2 Areas of interest

In regards to the course, participants chose which subject area(s) most interested them. As seen in Figure 11, the overall most popular areas were aesthetics and technology of the products. However, when these results are compared against the most popular courses using co-variance, as shown Figure 12. It appears the interests such as technology, materials and electronics of products are prominent with product designers as opposed to industrial designers focusing more of the aesthetics and technology, but very little on electronics. Both can be said to have a similar interest in usability.

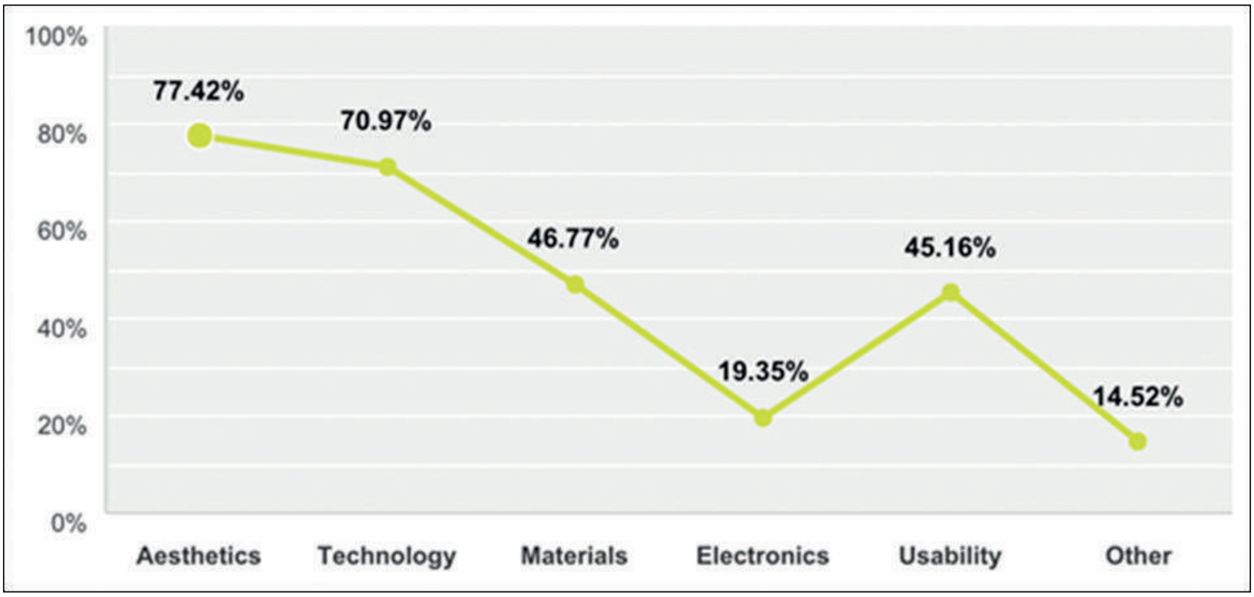

Figure 11: Subject area interests

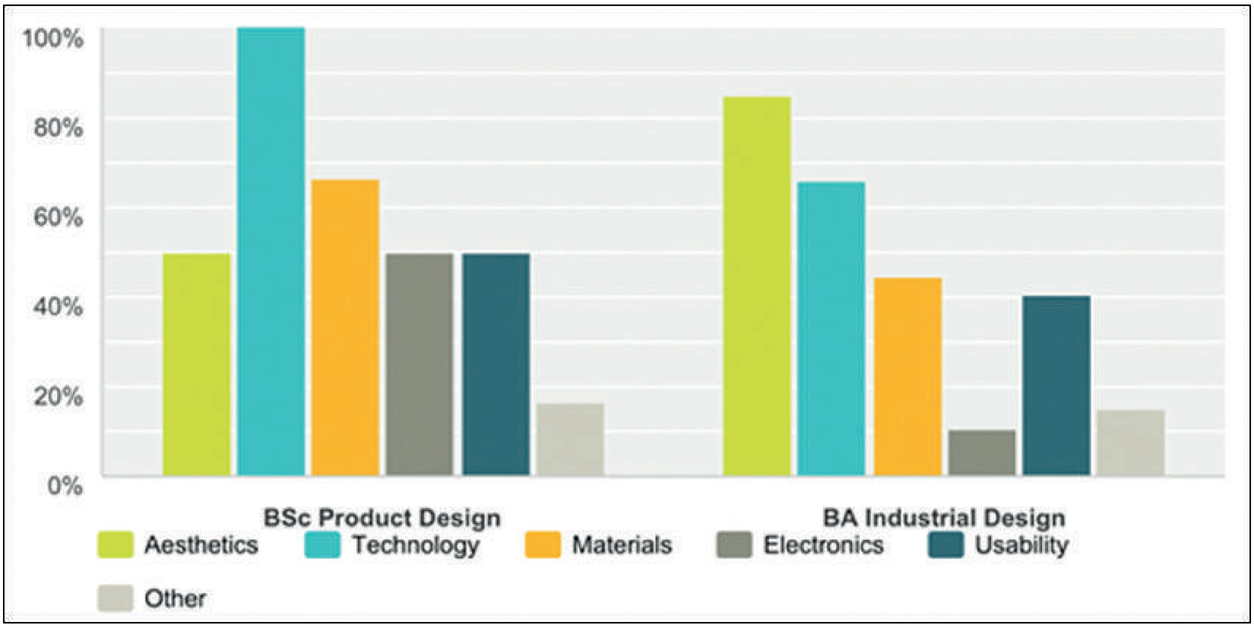

Figure 12: Subject area interests by design course

4.1.3 Interest of the concept and potential module
The results showed that overall interest into the IoT concept was high, with an average of 3.53, comprehending to a higher than neutral interest shown in Figure 13. Correspondingly, when participants were asked how interested they would be in taking a module in the subject using the same scale rating, shown in Figure 14, the results showed a very similar, although slightly lower average score of 3.52. Therefore, it can be assumed that a common interest into both the concept and a module in the IoT.

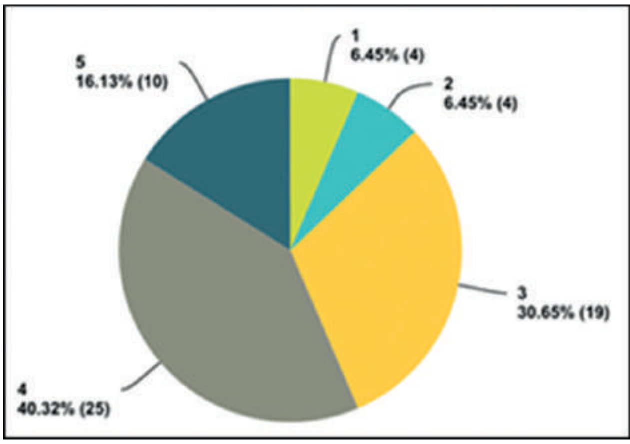

Figure 13: Interest in the IoT concept

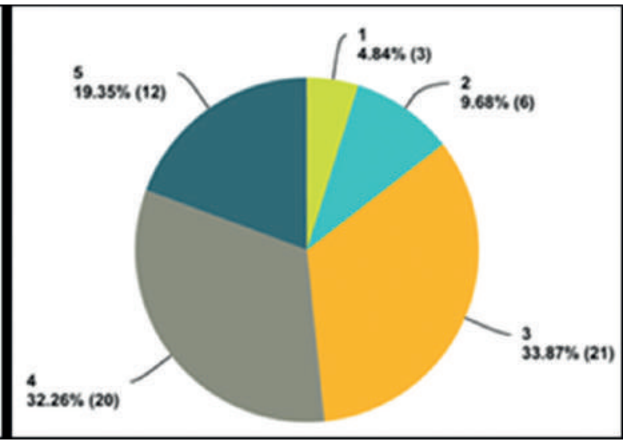

Figure 14: interested they would be in taking a module in IoT

4.1.4 IoT as a Module

All student participants were asked how they might envision a new IoT based module, between 10 or 20 credit modules, resulting in a 19:12 ratio in favour of a second year, 20 credit module, as seen in Figure 15, and therefore representing the more popular option amongst the population of students across all years and design courses.

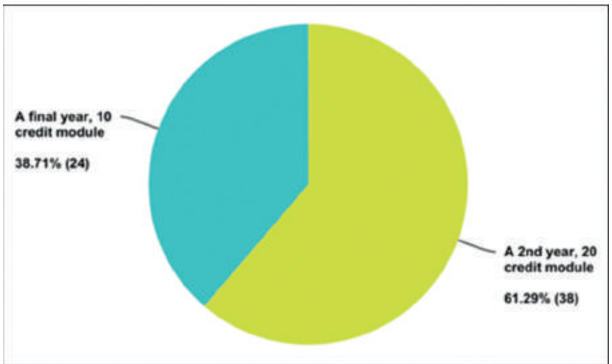

Figure 15: IoT module choices

4.1.5 The future of the IoT: Markets, Designers and Education

A series of final questions relating to opinions regarding the future of the IoT were asked using a Likert scale of 1 representing a strongly disagreeing opinion, and 5 a strongly agreeing opinion. The results and analyses are as follows: 'Designers need to design for connectivity in order to develop and build markets'. An analysis of this question reveals a majority 58.04% agreed with this statement, with an average score of 3.56, as seen in Figure 16.

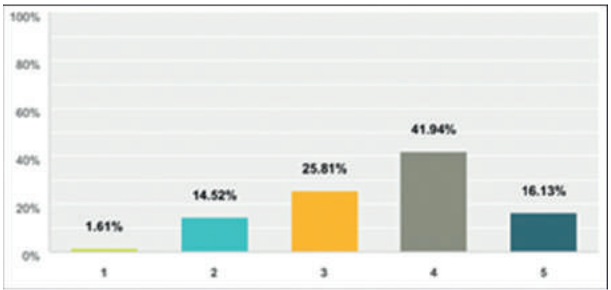

Figure 16: 'Designers need to design for connectivity in order to develop and build markets'

'The IoT is a challenging vision to achieve through teaching in design courses'. Data for this statement reveals an average of 3.42, although 51.61% of participants agreed or more, as shown in Figure 17.

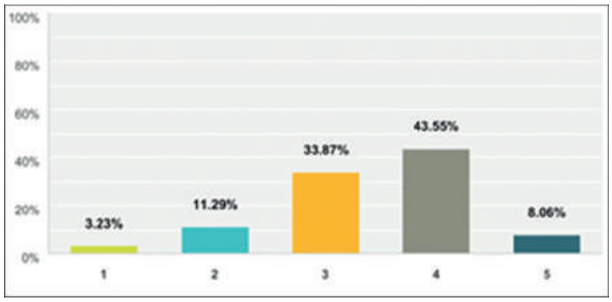

Figure 17: The IoT is a challenging vision to achieve through teaching in design courses'

'Application of the IoT in product/industrial design is key to its development and success'. The results from the final statement show similarly a 51.61% agree rate, however with a 3.45 average, as shown in Figure 18.

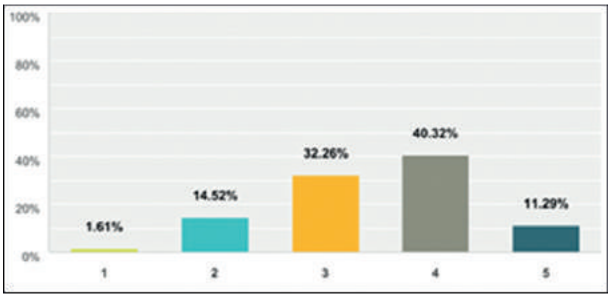

Figure 18: Application of the IoT in product/industrial design is key to its development and success'

5 DISCUSSION

5.1 The Internet of Things Concept

The term 'the internet of things' is a complicated subject to understand due to the fact that it is an 'umbrella phase' collectively consisting of visions, applications, features and descriptions. Similarly, like most emerging concepts, the definition is not yet fully explored or agreed upon. However, the phrase has become popular within the past number of years, not only in the technological community but amongst the general public; resulting in an appealing name replicated by the mass media, in which a common, simple definition is now widely accepted. Specifically, this general definition and hype of interconnected 'things' noticeably exists in the current student and staff population at the design school.

As the concept is emerging, it allows us to question the reliability of the future predictions. Research shows that just as applications are already being released, IoT will be the next big thing set to fully impact the market within the next 5 years and generate $300 billion in revenue through potentially 50 billion connected devices. There is no doubt of a huge potential and genuine human benefits however, with multiple restraining challenges and threats such as privacy and data protection, it is difficult to realise these predictions. We as a community must be assertive to these dangers as well as opportunities and not fall into the risk of taking it for granted. If not, the IoT concept may exist only as a short-lived hype with delayed success, similar to other concepts in the past. If IoT is to be realised within predictions, it must be from multiple perspectives in order to reach maximum potential. This will take time and a tremendous amount of effort from both individuals and corporations; not specifically from a technological point of view, but also from an application one.

5.2 Interest for Industrial Designers

Market research shows an emerging visible interest for consumer product sectors, from large corporations to smaller start-ups. Additionally, the results of quantitative research conclude that within the current student demographic, there is a higher than average interest collectively across all design programs with statistically 56% interested; theoretically equating to 312/553 students. For young designers within possible applications frames, even those yet to be identified, the IoT is an expanding interest for the future. This can be expected in the context of the current hype and state of the concept. Moreover, this basic interest is echoed within the staff population, specifically in the understanding 'if you are a designer, naturally you will be interested'. Contrastingly from a technology perspective, it can be said that collectively as designers, we are less interested in how the technology works, but what we can do with it and how we can use it in our designs. With these potential product applications however, we must be sceptical of not buying into the concept for the sake of it. As participant 6 claimed 'there is a real opportunity for products but as designers, we must focus on matching technical opportunity to real human needs' in which products with high values will survive the hype. Subsequently, not just the 'design' of successful IoT products is key but more importantly the system, interaction and experience. Consequently and agreed with by majority of industrial design students, it is revealed that designers are in fact key players in the IoT realisation.

5.3 The Internet of Things in the Design School

Discussion and hysteria surrounding the subject and its use for designers subsequently highlights the question: is there a place for the IoT in industrial design education? Quantitative results reveal that on average, 51% of students would enrol into a new module that focuses into the IoT, with the opportunity for an additional 34% to possibly join; resulting in an exciting prospect for the education system and industry alike. Literature into the subject suggests the technological trends in the world are always changing and updating, just as subjects such as sustainability have made an impact into the design education system, and in which exploration through education is at the forefront for IoT success. Furthermore, the survey responses concluded that a highly considerable majority of 85% of students agreed with this idea; design universities should update their curriculum for updating and emerging subjects.

However, interview responses argue that although we should update to meet the modernising world and supply students with the skills for these future IoT fields, the concept must be fully understood first in terms of interest, potential and subject matter, otherwise we are falling into the danger of blindly following hysteria rather than genuine technological excitement. Much like any new concept, this

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proves difficult, as only predictions and theories exist. The beauty of this is that students are equipped with a wide range of skills in which they are able to combine across various modules and projects. Successful and actually useful products are key to the IoT development and survival. With this being said, the design school can be seen as the perfect platform for students to use this range of skills, backgrounds and interests to identify opportunities and apply them, in which final year design students will have the potential to create very developed connected products. Therefore, it is not related to only learning technology in one area, but to independent learning and application of all areas.

The two main BA and BSc courses at the design school are different and research results show that BSc's are more interested in technology and electronics, which can be seen as fundamental parts of the IoT. The data revealed 92% of BSc students had at least an interest in IoT, compared to only 47% of BA students. This may be due to the fact that BA's are not so interested in the technology aspect. Arguably, this could be due to inexperience and a misunderstood potential for the concept in terms of industrial design as we previously explored from literature.

5.4 Possible Implementation and Realisation

Research findings have proven a wide range of ideas and issues regarding implementation. However, simply attempting to launch an 'IoT module' may not be the solution, with numerous flaws and challenges coming to light. This being said, students did identify a second year module as being more suitable than a final year module, however, 52% of design students also agreed that it is difficult to achieve through IoT teaching courses. One key factor that must be taken into account is that typically the timescale of introduction of a new module is two years; a year for application after a year's announcement notice. However, we must also recognise that this applies only to implementing a full, new module and results in a new problem of what does it replace? How do you define another subject as being obsolete?

It should also be recognised that a module in the IoT has the potential to expand the skillset of students for a wider range of applications, however, subsequently has the possibility to limit them. A challenge arises in that if a core module is created, projects in which require an IoT solution for the degree may in fact not be the best solution to the design problem. This is particularly hazardous in regards to final year projects, in which the student may have taken the IoT module in second year, and may therefore be pressurised to solve their final, and certainly most challenging design problem using their new connectivity abilities. Despite this, a common consensus from staff is a desire to see a truly IoT connected final prototype from final year students. Technology professor participant 1 suggested that solely teaching technology is not the way forward; it is only part of the bigger picture. This relates to Mattern and Floerkemeier's suggestion that success in IoT will not come from simply equipping 'things' with microelectronics. The concept of learning the IoT from opportunity is presented, in which students apply themselves in independent learning and application however, supported by more technological knowledgeable staff members.

Interestingly, it can be argued that the IoT is in fact already being 'practised' at the design school, at least on a conceptual level through a number of briefs in second year design practice and recent design week projects. These, of course, enable students to expand and apply their knowledge in the subject area but do not actually equip them with the prototype skills for application, in which participant 1 deemed 'essential'. Therefore a compromise between both application and acquired skill is required. Indeed, IoT does largely consist of technology and electronics, as they are the main driving factors. However, as research has shown, advances in programmable microprocessors now have the potential to allow a wider range of individuals to realise connected projects with minimal prior coding knowledge and with maximum ease which, most notably but not exclusively, allowing more interest and ability for BA students with less technological experience. Of these platforms, the Raspberry Pi is the victor, mainly due to its wireless connectivity ability over others however, the recently released mBed system can be seen also as a promising platform as it is specifically created for DIY IoT applications. However, this system must first be trialled and tested by technology professors before it can be concluded as worthy and successively, a theoretical input to the design school will be expanded to IoT.

Nevertheless, Professor Callaghan warns of the problems that can arise when attempting to teach the subject; in particular potential negative productivity and boredom through overly structured projects and a simple lack of time in sessions. This therefore makes it even more difficult to make the IoT into a specific, structured module. If IoT is to impact the material world as predicted, students should be equipped with the core abilities. Therefore, a compromise between technical ability and application should consist of basic knowledge of IoT, basic teachings of microprocessor platforms and a series of design challenges, where students must apply their prior abilities to identify and solve problems. This would not only give them the technological skills, but also expand their knowledge, capabilities and interests across all other modules. Furthermore, it wouldn't limit students to specific projects and would ensure that IoT abilities would be implemented, not just for the sake of using connectivity, but to solve real, suitable needs. Ideally, this would allow for a wider skillset for a wider range of FYDP projects and although in the future, potentially provide the IoT market with a 'gem' for global development and success.

5.5 Limitations and Constraints

There were a number of constraints within the research phase that must be identified as limiting factors for reliable results. Firstly, although appropriate time planning was applied, a limited number of questionnaire responses from the student community were collected and therefore results were unable to represent every individual. Subsequently, sampling was used to act as a representation of the population views, which can be seen as a limiting factor. In the same context, a limited number of staff interviews were used due to availability. Secondly, the nature of questionnaires resulted in a limitation of multiple choice answers, which may have caused a bias or false data. The study has only considered the curriculum relevance of the internet of things for undergraduate industrial design education in the context of the United Kingdom.

6 CONCLUSION

This research has provided a meaningful discussion and addressed, in which the different understandings, applications and visions of IoT have been realised. It revealed an opportunity for designers to impact upon the concept's development, specifically from educational institutes, such as design schools. However, there is a problem in finding a gap in the current industrial design curriculum for this opportunity. On one hand, there is a notable interest from students and tutors alike; on the other, despite much discussion, it is not yet clear exactly how and to what extent integration of the IoT can be realised in practice. Advances and experimentation with microprocessors appear promising as a means of functional application for all students with varied technological experience. However, due to the timeframe and certainty needed to introduce a new module, it is concluded that implementation should begin initially through existing electronics modules for a technological introduction approach, and although already beginning, further IoT conceptual briefs across other modules.

As this research contained limitations and constraints regarding sources, time factors and availability, further research would be valuable to the topic. Suggestions would include qualitative research from wider range of sources, such as experts in the IoT field and additional design tutors and students at the Design School to expand upon the research already conducted. Additionally, comparable to the implementations of other similar topics, there is also a potential for a module trail in which ideas would be tested and applied through a focus group in order to analyse interest, ability and technological functionality for future implementation.

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