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Workshop

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Exploring the Future of Immersive Education

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Abstract. This extended abstract describes the #iLRN16_SFP workshop which opened the iLRN'16 conference held in Santa Barbra, California USA from the 27th June to the 1st July 2016. The main focus of the workshop was exploring future trends and expectations for research into immersive learning. The event was a collaboration between the Creative Science Foundation and the Immersive Learning Research Network.

Keywords: Virtual-Reality, Immersive Learning, Mixed Reality, Ideation, Innovation, Science-Fiction Prototyping, Creative-Science.

Introduction

The focus of the workshop was to explore how current research might be imaginatively extrapolated to explore the possible ways immersive-reality technology might change future education. In doing this, it took a very broad vision for the delivery of education stretching from formal education at (say) university through industrial training to informal settings.

2 Methods

The workshop adopted the *Science Fiction Prototyping* method which was proposed by the futurist, technologist and author Brian David Johnson, a Professor of Practice in the School for the Future of Innovation in Society at Arizona State University in Phoenix who also provided the keynote at this event. Essentially, the method involves writing short fictional stories that imaginatively extrapolate current practices forward in time, leaping over incremental developments, exploring the world of disruptive product, business and social innovations. Because *Science-Fiction Prototyping* adopts a rich story-based structure it is able to create high-fidelity analogues of the real word, enabling it to act as a type of prototype to test ideas. In more practical terms the workshop followed the '*Imagination Workshop*' ideation methodology devised by Hsuan-Yi WU of the National Taiwan University. This workshop adopted a genre of Science Fiction Prototyping called µSFP where the participants wrote Twitter-size fictions to illustrate some future possibilities for immersive education research.

3 Workshop Structure

The workshop followed a fairly conventional structure as shown below:

- Welcome to iLRN
- Invited talk (Brian David Johnson, the creator of the SFP method)
- Introduction to SFP
- Imagination Workshop (brainstorming, selecting ideas & writing a µSFP)
- Group presentations, voting and prize for best µSFP

4 Competition

To mix some fun with serious research the conference attendees were invited to enter a Twitter-based competition to write an individual *µSFP* that described how they foresaw immersive learning technologies and pedagogies changing the nature of future education. To enter they were asked to tweet their stories to ***#iLRN16_SFP,* the name of this workshop.** The top 3 *µSFPs* (as voted by attendees) received a prize (an Amazon voucher) which was presented at the closing session of iLRN 2016.

5 Outcomes

The workshop outcomes were posted on:
http://www.creative-science.org/activities/ilrn16_sfp/

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Special Track 2: The Future of Education

An Online Immersive Reality Innovation-Lab

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Abstract. This paper introduces the concept of online '*Innovations-Labs*' (i-Labs) as location-independent collaborative ideation spaces. We highlight the challenges and opportunities that disruptive innovations present to companies and society, and discuss how *Science Fiction Prototyping* and *Diegetic Innovation Templating* can provide a means to explore that space by acting as ideation process and a language for capturing and communicating innovations. A core hypothesis of this paper is that there are significant gains to be accrued from integrating *Virtual Reality*, *Science Fiction Prototyping*, *Diegetic Innovation Templating* and *Innovation Labs* to form an online immersive reality innovation-lab which both offers better affordances and access to people wishing to undertake innovation related activities. We present details of our initial implementation of an online innovation-lab (*Our HEX*) which takes the form of a virtual-reality space-station. We then conclude the paper by describing future directions of our work, principally, a venture which uses '*Our HEX*' space-station platform, plus a supporting textbook published by Tsinghua University Press, to teach '*English, Computing and Creativity*' to Chinese students. Finally the paper concludes with a summary and reflections on our work to-date.

Keywords: Virtual-Reality, Innovation-Labs, Ideation, Innovation, Science-Fiction Prototyping, Diegetic Innovation Templating, Creative-Science, EFL.

1 Introduction

It is generally agreed that innovation is an essential component for economic growth and productivity. A recent report by PriceWaterhouseCoopers, the largest professional services firm in the world, found that "*Five years ago, globalisation would have been the most powerful lever for growth and every business would have been talking about China. But now, the growth lever that has the greatest impact is* innovation. *Ninety three percent of executives tell us that organic growth through innovation will drive the greater proportion of their revenue growth*"[1]. Thus it's hardly surprising to find that governments around the world place a huge importance on supporting innovation activities although how they do that varies widely, depending on various political and financial factors. While innovation sometimes appears to be rooted in the individual (eg Steve Jobs) from a government perspective it is a product of a *National*

Innovation System (NIS) that includes all economic, political and other social institutions affecting innovation (eg education, financial structures, regulatory policies, labour markets; culture etc). For example, China operates a NIS derived from their 15-year national plan *(2006-2020)*, the '*National Outline*', which contains a section that focuses explicitly on creating nation-wide structures favourable to innovation [2]. In contrast the USA has not adopted a centralized approach rather, being a country that grew out of the notion of free enterprise and thinking, innovation was more easily established as it was part of the underlying 'DNA' of American culture. That is not to say that government policy does not play a role in fuelling American innovation, just a lesser one than in most other countries. It is difficult to measure a countries innovation capacity but one metric is the number of patents that are registered annually. Those statistics place the EU, USA, Japan and China in leading positions, aligning well with their economic performance. Because of the importance of innovation to companies and national economies, there is a huge incentive for companies to find tools that can aid the process of innovation. Once such tool is *Science Fiction Prototyping*, an ideation and communication tool that was first proposed by Brian David Johnson while he was working for Intel Labs in Portland. The basic principle of the method is that the stakholders of the innovation create futuristic fictions as a means of unleashing their imagination plus communicating and testing the ideas [3].Another tool is *Diegetic Innovation Templating* which uses existing fiction as an inspiration for new innovations (eg the flip-phone being inspired by the Star-Trek communicator) [4]. Innovation works better with a group of people where they can spark ideas off each other and the limited knowledge of an individual can be supplemented by others. One popular group-based approach is the *Innovation-Lab* (i-Lab) which offers a specially designed environment that is conducive to creative thinking [5]. For example, i-Labs provide participants with a relaxed comfortable setting where they can contribute ideas anonomously during ideation sessions. Generally, i-Labs require the participants to be physically present in the same location. However, the advent of vitual-reality has opened up the possibility of an i-Lab being located online in a virtual space which allows participants to be locacted anywhere in the world, and to ulilise tools that would not exist in the physical world. Thus, this is the aim of the work in this paper, to explore the potential arising from combining i-Labs, virtual-reality and science-fiction prototyping, diegetic innovation templating to create a novel online innovation facility which will be described in the following sections.

2 Related Work

2.1 Innovation Labs

An innovation-lab (i-Lab) has been described as an "*inspirational facility designed to transport users from their everyday environment into an extraordinary space encouraging creative thinking and problem solving*" [5]. The i-Lab concept was based on a model created by the UK Royal Mail's '*Futures and Innovation Group*' in 1997 for the purpose of helping their management teams brainstorm future possibilities. In

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doing this it became apparent that the interactions within the groups, together with the conversational and session management tools played a significant role in the effectiveness of the sessions, leading to the idea for providing specialist environments to support these activities.

In transferring the i-Lab concept from the original Royal Mail environment to the wider world there have been three notable projects. The first was the '*Learning the Habit of Innovation: Harnessing Technology for Strategic Planning*' (LHI) which was a collaboration between the UK Royal Mail and the universities of East Anglia, Cambridge, Essex, Bedfordshire plus Anglia Ruskin University. It was operated out of the University of East Anglia from 2001-2004 and funded by the Higher Education Funding Council for England [6]. The project sought to transfer the i-Lab model created by the UK Royal Mail into higher education and involved formalising a template that would form a minimum set of conditions to recreate an innovation environment. In brief they deduced that an i-Lab required three interlinking components namely the *environment*, the *technology* and the *facilitation mechanisms* to make it suitable for ideation and innovation activities. Furthermore, they determined that an iLab session comprised some mix of the following activities (most electronically supported):

- Icebreaker and reviver activities
- Discussion & getting other people's perspectives
- Brainstorming & voting
- Headlines, cut & paste collages and PowerPoint presentations
- Wall activities (collaborative writing, doodling etc)
- Scenario building
- Role play

They emphasised that creative thinking was not necessarily a rational, linear process and that revisiting and refining ideas could be a productive way to progress. At the core of the process was brainstorming, a technique for unleashing a flood of thoughts driven by members sparking ideas off each other, or carefully injected external stimulus. Having generated sufficient ideas a group would go on to categorise, rationalise and vote on the suggestions. Implementing the ideas is more challenging and occurs beyond the i-Lab session.

The two other notable ventures were EU Leonardo da Vinci collaborations between educational institutions from Poland, Greece, Romania and Turkey, coordinated by the University of Essex in the UK around two projects, namely '*The European i-Lab Competences Development Programme*' (2006–2008) and '*The Innovation Laboratories for the Quality Assurance of Vocational Education and Training'* (2012-2014) [7]. These projects led to the establishment of three innovation laboratories in Poland, Turkey and Romania and the production of a standard guide for i-Labs, namely the '*Innovation laboratory – Good Practice Guide*' [8] all of which aimed at the promotion of i-Lab use throughout Europe which, today, has resulted in over 100 globally-located i-Labs (from social to technical) created by organisations as diverse as the Standard Bank, Walmart, John Lewis, the UK National Health Service, Ryan Air and government (eg New York's 'Public Policy Lab' or the 'Social Innovation

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Lab for Kent') [15]. In respect of this paper, one of the most significant i-Lab developments has been the introduction of web-based software which provides a much more efficient (and faster) ideation process together with providing an anonymity component [9]. Moreover, this computerisation has enabled i-Labs to move into Cyberspace, allowing participants to be freed from the need for physical co-location, a feature we build on in our online version of an i-Lab (*Our HEX*).

In our work, we use brainstorming as part of a product-innovation process called *Science Fiction Prototyping* that will be explained in the following section. In this we adopt a procedure procedure called an *Imagination Workshop* which was first proposed by Wu in 2013 and is similar to the brain-storming process used in an i-Lab except it uses science fiction and fantasy ideas to extrapolate forward current technologies, business and social practices by ten-plus years [10]. These concepts will be explained in the following section.

3 Creative Science

Creative Science refers to creative methods for supporting science, engineering, business and socio-political innovation through various imaginative activities. For the purposes of this paper those mostly concern *Science Fiction Prototyping* (SFP) and *Diegetic Innovation Templating* (DiT).

3.1 Science Fiction Prototyping

As was mentioned earlier, *Science Fiction Prototyping* was proposed by Brian David Johnson, Intel's then Futurist, as a response to a particularly difficult innovation challenge Intel faced in designing new generations of integrated circuits. Their challenge was that it takes between 7-10 years to take an integrated circuit from concept through to production and, during that period, there can be as many as 6 generations of potential applications for it. For example, new models of mobile phone can be released as frequently as every 18 months. Thus, chip designers needed to anticipate applications 7 years' ahead of specifying a chip (and possibly longer as the applications may live on for another 15 or more years) which, in a rapidly changing world, presents a formidable challenge! Of course an even bigger worry is the risk of disruptive technologies coming along. Thus, there was a compelling case for Intel to find a creative-thinking process that might come to their aid. Their solution was *Science-Fiction Prototyping*. Essentially, the method involves writing short fictional stories that imaginatively extrapolated current practices forward in time, leaping over incremental developments, exploring the world of disruptive product, business and social innovations. Because *Science-Fiction Prototyping* adopts a rich story-based structure it was able to create high-fidelity analogues of the real word, enabling it to act as a type of prototype to test the idea. Moreover, being a story it was accessible to anyone (aka the old adage '*everyone likes a story*') making it a perfect vehicle for conversations between all the stakeholders of the innovation, including society at large (the customers of innovations). The outcomes of *Science-Fiction Prototypes* are used to create new kinds of products, businesses or socio-political structures etc.

3.2 **Science Fiction Prototypes Style**

The most common size for a *Science Fiction Prototype* is 6-12 pages (referred to as a *mini-SFP*) which is of a similar size to a conference paper [10]. However, 6-12 pages can take many days to write so for innovation sessions, that need to take place in less than a day, an even shorter form of *Science-Fiction Prototype* was developed; the *Micro-SFP* (or µSFP) [11] which will be described in the following section.

3.3 Science Fiction Prototyping Workshops.

Typically, science fiction prototyping based innovation sessions take the form of an *Imagination Workshop* [14]. It involves gathering together a group of participants, specifying a goal (eg a new business or product etc), providing a context (eg business, home etc), setting a timeline (eg usually 10+ years into the future) and offering support for brainstorming about possible futures. A World Café approach is adapted to stimulate brainstorming and discussion with participants being placed in small groups (eg 5-7 members). Most other aspects are similar to an i-Lab.

3.4 **µSFP- A Shorthand Innovation Language**

There is no agreed specification for micro-fiction but, given the close relationship of *Science Fiction Prototyping* to technology perhaps it is not surprising to discover a popular size for a *µSFP* is one that fits mobile phone text (160 characters) or Twitter messages (140 characters) which, in English language, equates roughly to 25-30, words. Since *µSFPs* are short, they have the advantage of being quick to write, enabling users to capture and create many ideas in a short time period, in a similar timescale to brainstorming. Thus, *µSFPs* are seen as being complementary to brainstorming, providing a means to wrap a brainstormed idea in a more story-like framework which provides added meaning. From another perspective *µSFPs* are an interim step between a raw idea and a full *Science Fiction Prototype*. By way of an illustration of the principle of *µSFPs*, consider the following example:

> *Zoe, you've been my life-long friend on SentiBook; today the news feed reports most social network friends don't exits, are you real?* (22 words, 133 characters)

This *µSFP* extrapolates forward in time the current trend of companies adopting ever-more more automated customer call handling systems but explores the consequences of such technology reaching out more widely, for example into email and social messaging systems. It raises the question about whether we will know, or even care, if the parties we are communicating with are real or artificial. In this particular example the *µSFP* observes that our lives are becoming increasing virtualised through, for

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example, friendships on social networks with people we may never have met physically. As AI advances, machines will be better able to mimic real people, raising all kinds of new opportunities and conundrums.

Following the creation of a *µSFP* the next step would be to expand it into a *mini-SFP* (a 6-12 page version with a rationale and comments), followed by the usual product development cycle involving pre-production prototypes etc.

3.5 Diegetic Innovation Templating

Diegetic Innovation Templating (DiT) is a process of extracting creative ideas (eg innovations) from fictions created for the purpose of entertainment, rather than for technology, social or business innovation. Thus they are typically science fiction or fantasy movies or TV series such as, for example, Star-Trek that taps into the creative abilities of great authors and filmmakers as source of creative ideas. The term '*diegetic*' is borrowed from film studies and refers to things which are embedded into a fiction, playing an integral role in the story, such as the use of a gadget by one of the characters, and seen through their eyes. The artistic nature of such productions makes them particularly useful for non-technical applications or for situations where writing bespoke fictions is not a good option. For example it has been used by one of China's leading fashion design houses (Sunfed) where it levers the advantage from popular fiction being embedded into socio-cultural contexts (ie the firms marketplace) aiding branding and marketing efforts [12].

3.6 Out of the Box and into 'Our HEX'

By way of a summary of this section, we introduced *Science Fiction Prototyping* and *Diegetic Innovation Templating* as tools to support the early ideation phase of the innovation process by providing a means to engage people's imagination in thinking '*out of the box*' about future possibilities. *Science Fiction Prototyping* also allows the ideas to be tested within a plausible narrative and provides a way of opening dialogues, independently of specialist domain knowledge, with all the key stakeholders. In the next section we will describe '*Our Hex*' a virtual spacestation which provides an online facility to host i-Lab activities based around the *Creative Science* concepts we have presented above.

4 **The Virtual Spacestation** (on online Innovation-Laboratory)

4.1 A Spacestation Based i-Lab

Since *Science-Fiction Prototyping* concerns thinking about high-tech futures, the idea to base the online i-Lab on a simulation of a spacestation was born. The first version was funded by the *Creative Science Foundation* as a way to explore the concept of '*free will*' raised in Brian Johnson's original *21st Century Robot* science fiction prototype [13]. Our current online innovation lab is a modification of that early virtual-reality spacestation and consists of a large central arrival area (Social Deck) leading to an, essentially, unlimited number individual rooms, each outfitted to resemble an i-Lab.

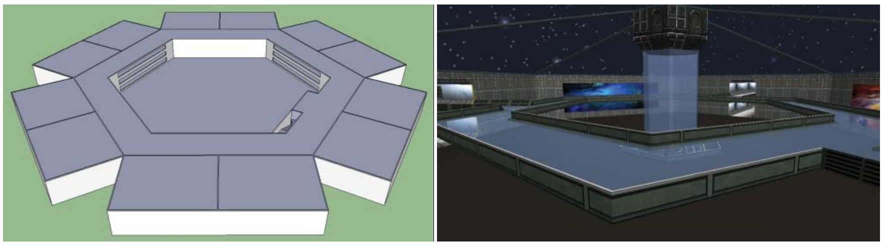

Fig.3. '*Our 'HEX*' Spacestation (Layout & Prototype Interior).

The spacestation structure was inspired by the *Hexagon Restaurant* (affectionately referred to as "*Our HEX*") at Essex University (now defunct) which is shown with 6 pairs of i-Labs (Fig 1) but, in practice, since i-Labs are simply software instances, there is no fixed number as they can be created on-the-fly, as required. In keeping with the list of functionalities listed earlier, each simulated i-Lab includes a communal electronic white-board, a set of anonymised editing stations (so ideas and comments can be written to the white-board without identifying the writer) and facilitator tools for managing and archiving the sessions.

Fig. 2 – The Unity 3D Prototype iLab space station (clockwise from the top left there is the Social-Deck, one of the radial connecting corridors, an i-Lab entrance and a view of an i-Lab)

With reference to figure 2, each user who accesses the virtual world (ie logs in) first appears in the central arrivals area (the Social Deck). From that location they are free to walk around the environment; interacting with any displays they encounter (eg display boards showing outputs from earlier science fiction prototyping, diegetic innovation templating sessions, or interactive display boards where they can participate in competitions to evaluate innovation outputs, or just read notices of other events). The central area has corridors leading to each of the different i-Labs. In each i-Lab, users are able to participate in Imagination Workshop sessions (described earlier). Teachers and facilitators are able to observe, assist and rate student work.

The prototype of '*Our HEX*' was implemented using Unity-3D, an online gaming engine. Being an MMO cloud based virtual world, users are able to log into the environment via a link from the website of the Creative Science Foundation (CSf). The spacestation's i-Lab server resources are provided by a cloud based system. The execution-engine currently supports a Java runtime environment structured in a modularised client / server arrangement to facilitate future expansion. While a working prototype of the spacestation has been built (a video walkthrough is available at http://www.youtube.com/watch?v=-i6ki5YHGZc) there are a number of aspects that require completion before the system can be publically deployed, most notably creating a full gamut of i-Lab facilitation tools plus completing a formal evaluation with students. In addition the platform's user-guide needs to be integrated with the Tsinghua University Press textbook. Thus, '*Our HEX*' is a 'work-in-progress' task with functionality being added continually in response to user needs. To provide an insight to our immediate work-plans, the following section describes our next steps.

5 Deployment Plans

Currently '*Our HEX*' is being operated with a closed group of students at Shijiazhuang University, China, who follow a *Computer English* course [17] based on a carefully crafted Tsinghua University Press textbook [18].

By way of some background, in China it's mandatory for universities to teach "*Public English*" to all their students as this is seen as a necessary skill for them to thrive in a global business environment. For computer science students this requirement is translated into the provision of a specialized English module called '*Computer English*' that is usually delivered to students in their 3rd or 4th year [19]. By combining English Language with Computer Engineering, the course is made relevant to the student's studies [20] [21].

Beyond learning English, another vital skill for a workforce with aspirations to compete in global markets is an ability to innovate, which *Science-Fiction Prototyping* supports. Thus the proposition to integrate learning English Language, Computer Science and Innovation via an engaging new course was born, leading to a pilot trial being conducted by Zhang at Shijiazhuang University during the period 2014-2016 [16]. Following the success of this trial (student motivation and performance were demonstrated to sharply increase, with one student even publishing his SFP in an international workshop [22]) the team worked with Tsinghua University Press to produce a textbook that has been made available across China [18]. In support of this venture, we are planning to use the '*Our HEX*' spacestation platform as a means to widen access to innovation-lab facilities across China and the rest of the world. As part of this vision, in the longer-term, we plan to address other languages such as Spanish.

Thus, “Our HEX” functions as an online school to teach ‘*English as a Foreign Language*’ (EFL) based around Creative Science, which brings the additional bonus of training students in creative thinking and innovation. In terms of the potential for this venture, the market for teaching English is estimated to be worth some $5 billion or more. In China alone there are an estimated 250 million English learners, increasing by 20 million per year, with a requirement for 1 million English teachers, which has led to the emergence of a plethora of enterprises seeking to satisfy these needs. Examples include *Ivy League English*, founded in 2009 by graduates of the Massachusetts Institute of Technology, which provides an app that connects students with USA-based business coaches for real-time roleplay activities (www.ile-china.com/), the 2013 Kickstarter funded start-up, *Influent*, that created a video game designed to introduce foreign vocabulary to learners by them exploring an interactive 3D environment filled with hundreds of selectable objects (www.playinfluent.com) through to full blown MOOCs learning platforms such as the Shanghai based *Hujiang* which has grown to over 90 million registered users since starting in 2001 (www.hujiang.com/). Hence, this venture joins a fairly crowded marketplace but differentiates itself by offering a novel combination of science, creative-thinking and language learning, especially tailored for university based Computer Engineering students through a supporting Tsinghua University Press textbook.

From the earlier sections it can be understood that creative science exercises English language by requiring students to read and write short stories plus undertake group work via brainstorming and presentations (and, as a by-product, getting other useful skills such as creative thinking and product innovation). Because, this involves group-work there is a space issue since, ideally, each group would have their own dedicated space (room). Clearly, in most situations that is impractical. For example, in the case of Shijiazhuang University's ‘*Computer English*’ course, their 160 students would require some 23 rooms (assuming maximum group sizes of 7 students). Thus, ‘*Our HEX*’ overcomes these space limitations as well as broadening participation to students, independently of their geographical location. In addition, given the virtual nature of the space, it is simple to outfit it with simulations i-Lab tools (ie an electronic white-board, anonymised editing stations and computerised facilitator tools) making it a virtual innovation-lab that can be replicated with little cost.

While our current focus is on creating an online “*English as a Foreign Language*” school we have been considering other longer-term possibilities for ‘*Our HEX*’. In terms of language training it would be possible to enrich the activities by including online role-play [23] [24]. Beyond language training, clearly one major application is as an online Innovation-Lab which would aim to satisfy the growing commercial demand for innovation services and we are working with a Taiwanese start-up, LivingPattern Technology Inc to explore these possibilities [25]. Other possibilities include collaborating with the Creative Science Foundation to host an online version of their vacation ‘*Entrepreneurship Schools*’ (http://www.creative-science.org) or working with FortiTo Ltd to create online ‘*Maker Schools*’ (www.fortito.mx)..

5.1 Deployment Platforms

A key issue is the cost of accessing this service. As a consequence we developed the system to work with a range of technologies to better fit the user's resources. These range from commonplace technologies such as mobile phones, pads, laptops and desktops, to more sophisticated devices such as virtual and augmented reality glasses (see figure 3).

Being a virtual-reality environment, '*Our HEX*' has the potential to simultaneously offer a number of different user experiences, depending upon how an individual chooses to interface and interact with the world. For example, whether the world is viewed from a first or third-person perspective can significantly alter the relative experiences of individual users, especially when working with others in team-based exercises. Furthermore, technologies such as VR headsets, (e.g. the *Oculus Rift*, or *HTC Vive*) could be used to generate a more immersive experience in the minds of users, allowing them to move around '*Our HEX*', with the impression of actually being transported inside the artificial world. Mixed reality interfaces, such as the Metavision's Meta-2 or Microsoft's *HoloLens* system, could also potentially be used to superimpose fragments of the spacestation onto the real world, effectively turning a physical room or other location into an extension of the '*Our HEX'* environment. Such an arrangement could facilitate interaction between groups of people where several are sharing the same physical space but wish to interact with other remote users present elsewhere in '*Our HEX'*.

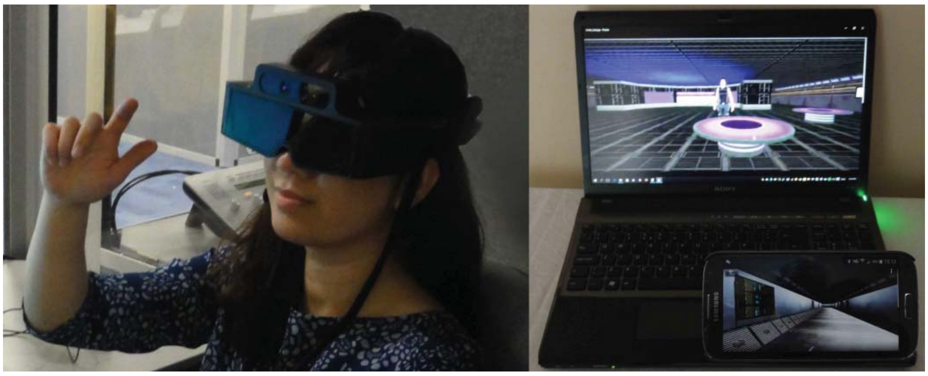

Fig. 3 – Some platforms for "*Our HEX*" (picture courtesy of Dan Chen)

As mentioned earlier, '*Our HEX* was implemented using *Unity 3D*, a professional tool used for the creation of computer games. The decision was made to use a game engine as an implementation platform in order to take advantage of some of the available graphics, physics, networking and other technologies developed by advancements in the computer games industry. Another reason was to give users some familiarity via a common interface, with many of the controls being identical to those used in PC games, (e.g. WSAD movement controls). By making the user as comfortable and immersed as possible in the '*Our HEX'* environment, their user experience should be enhanced and hopefully create a more productive innovation or education session. Other computer games technologies that may be beneficial to a learning/innovation environment are also being explored for potential integration with the '*Our HEX'* system. For example, live streaming services, such as *Twitch*, could be invaluable for a teaching experience, as users could both visually see a live representation of their teacher and provide feedback or ask questions via the text chat feature. From a business perspective, live streaming services could have potential benefits such as revenue generation from advertising and subscriptions or tips from users. Recordings of past broadcasts can also be played back on-demand by users.

6 Summary

This paper has described how we developed an online creative space which integrated *virtual reality*, *science fiction prototyping*, *diegetic innovation templating* and *innovation-lab* concepts to create a novel shared ideation space. We argued that the synergy derived from this linkage introduced significant new opportunities for those seeking to undertake innovation activities. For instance virtual reality both provides a more engaging and functional space, together with widening participation. We also argued that the inclusion of creative science tools provides a particularly good approach for exploring disruptive innovations as it levers people's imagination through the use of futuristic science fiction to offer more radical perspectives on the future. We also explained that a story based narrative provides an effective way to facilitate communication between professionals and lay-members of society, who frequently lack a shared vocabulary to converse (articulated by the mantra "*everyone likes a story*"). Finally we described how, in support of the book we have published with Tsinghua University Press in China, we are exploring the application of the '*Our HEX*' spacestation platform as an aid to students learning a combination of English language and innovation. Clearly this work is at an early stage and we will look forward to reporting on further progress in later conferences.

Acknowledgements

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Virtual Observation Lenses for Assessing Online Collaborative Learning Environment

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Abstract. The purpose of this paper is to introduce a new approach for assessing learning outcomes from collaborative work in 3D virtual environments. It represents a novel computational framework that improves recording and observing collaborative activities between students to evaluate learning outcomes. The framework includes a virtual observation model that maps observing learners in classrooms with observing and assessing the students in 3D spaces. This can be accomplished by applying a mechanism that combines natural agents and software agents to support collecting learning evidences from virtual activities and simulate the educators' observation(s). Such a novel framework will solve issues that could develop from evaluating students' performance, interaction, skill and knowledge in collaborative virtual learning environments.

Keywords: E-learning; 3D Virtual Worlds; Assessment; Virtual Observation; Collaborative Learning; Learning Evidence; Software Agents; Natural Agents.

1 Introduction

The power of networks and computers has invented technologies that support learning and connect geographically dispersed learners to enhance learning experiences. Several educational technologies have been widely applied that connect scholars and educators to provide different types of activities and to access learning sessions remotely without requiring physical attendance. By using online environments, organisations could easily educate learners and support collaborative learning without offering physical place or hiring educators.

A great technology that enables virtual collaborative learning is the immersive environment, the 3D virtual worlds (3D VWs). The 3D spaces are increasing in popularity because of many features that distinguish them from other online systems. They connect students in real-time and enhance interactivity, exploration, and engagement between them. Moreover, they facilitate investigation of ideas, situations and places that cannot be reached physically; delivering learning processes; providing

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realism of interaction, discussions and activities of even the most complicated topics in simpler conditions with less cost.
Collaborative learning can help students to achieve learning through working with their peers, who support them to enhance their information and skills, resulting in constructing new knowledge and experiences. Learners usually obtain new knowledge while participating in learning sessions, so evaluating learners in a group should not be applied just after the last learning session, but it should also be applied during the learning process. Wells [1] also stated that educators should evaluate the whole learning process when performing collaborative learning activities rather than look at the final artefact as evidence of learning.

However, numerous issues can arise when assessing learning outcomes for a group of students in the 3D environments. Firstly, observing users' behaviour dynamically and collecting evidence of learning are complex tasks in VWs. Secondly, various skills, including communication and negotiation skills, can be gained from collaborative activities, but it is difficult to automatically detect evidence of them in these spaces. Thirdly, labelling and recognizing the evidence of many users in real-time is difficult because several students are contributing at the same time, which makes tracking the evidence much more complex. Therefore, finding an event detection method that can dynamically recognise users' behaviour, collect learning evidence data, and analyse events to measure the learning outcomes, is necessary. Gardner and Elliott [2] indicated that 'learning within technology creates a pedagogical shift that requires teachers to think about measuring outcomes in non-traditional ways'.

The purpose of this paper is to introduce a new approach for assessing learning outcomes from collaborative work in 3D virtual environments. It represents a novel computational framework that improves recording and observing collaborative activities between students to evaluate learning outcomes. The framework includes a virtual observation model that maps observing learners in classrooms with observing and assessing the students in 3D spaces. This can be accomplished by applying a mechanism that combines natural agents and software agents to support collecting learning evidences from virtual activities and simulate the educators' observation(s). Such a novel framework will solve issues that could develop from evaluating students' performance, interaction, skill and knowledge in collaborative virtual learning environments.

2 Related Work

2.1 Identifying Learning Evidence in Virtual Environments

Identifying learning evidence is simple in the multiple choice online test format, but it becomes more problematic in 3D VWs or educational games, because of the large number of observational variables and the complex relationship between these variables and students' performance [3]. Although technological improvements assist in recording data, even for difficult situations, understanding and analysing the composite data that results involves more complex processes.

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Certain approaches have been used to assess modelling learners' skills and knowledge in simulation learning spaces. The approaches can be categorised into two groups: 1) knowledge engineering/ cognitive task analysis approach and 2) machine learning/data mining approach. The knowledge engineering approach formulates logical rules to assess and group particular students' behaviours. The rules are also applied to differentiate the level of students' skills such as the study by [4]. In the machine learning/data mining approach, learners' behaviours are recognised by analysing data and extracting learners' performance from the log files that are auto-generated while students are participating. For example, learning evidence has been collected through analysing users' log data by applying cluster analysis algorithms to determine the key feature of students' performance in educational game environments [5].

However, the log files save all the players' responses to the given educational problems which creates enormous amounts of data that provide a serious obstacle for researchers when collecting learning evidence from immersive environments [6]. This makes it very difficult to capture individual students' learning, knowledge, and skills and challenging to identify the actions and performance that represent learning. Moreover, collecting data in simulation or virtual environments without consideration of how the data will be assessed or scored is an ineffective method for creating assessments. Hence, designing the learning environment from the beginning to enable assessment and collecting learning evidence is more preferable [7].

Additional issue with identifying learning evidence is that technologies cannot capture all of the acquired skills. Several skills can be gained from collaborative activities, but it is complicated to automatically detect evidence of them [8]. For example, the quality of the interaction skills between students including teamwork, collaboration, negotiation, and communication are hard to measure with regular assessments. The study [9] proposed techniques that permits assessing learning outcomes (skills, knowledge, and competencies) by using elements such as smart objects and avatars in 3D spaces. However, these techniques lack in measuring the quality of learning in collaborative environments.

Analysing various users' behaviour/data, identifying the meaningful actions, and combining those actions into learning evidence to determine the learning outcomes are very complex processes in such environments. Consequently, discovering techniques that could dynamically recognise learning evidence and analyse events to measure the quality and quantity of learning outcomes is advantageous. Developing such mechanisms will help to identify and gather proof of learning during collaborative activities in immersive worlds and correlate the evidence with learning objectives, to assess the overall outcomes of the learning processes.

According to Thompson and Markauskaite [10], 'educators need to move beyond traditional forms of assessment and search for evidence of learning in the learner interactions with each other and the virtual environment, and artefacts created.' Hence, we have considered another assessment method such as classroom observation which greatly assists educators to evaluate students by collecting evidence about their learning. We have mapped the physical observation to the 3D spaces to provide more insights of what evidence could be collected from students' performance. Section (2.2) gives more explanation of the observation method in learning.

2.2 Observation

2.1.3. 'Teacher observation occurs continually as a natural part of the learning and teaching process and can be used to gather a broad range of information about the students' demonstrations of learning outcomes' [11]. Observation takes place in several settings and with a variety of methods. It can help teachers gather information about the individuals' and groups' behaviours and skills. To distinguish the observation levels in classrooms, Gray [12] introduced conceptual frameworks that follow educational standards to define the basic frames for observing. Because observing classrooms is very complex, he suggests that each teacher should select a specific frame or 'lens' to gain more insight into a specific classroom characteristic. Such 'lenses' are summarised in Table 1.

Table 3. The Observable Signs Pertaining to the Eight-Question Areas [12]

1. The learning climate	• Degree to which students can express their feelings and opinions • Frequency with which student responses are used and extended • Amount of interaction and sharing among learners
2. Classroom management	• Use of preestablished classroom rules • Use of instructional routines • System of incentives and consequences
3. Lesson clarity	• Frequency of examples, illustrations, and demonstrations • Percentage of students who can follow directions given • Use of review and summary
4. Instructional variety	• Use of attention-gaining devices • Changes in voice inflection, body movement, and eye contact • Use of a mix of learning modalities (visual, oral)
5. Teacher's task orientation and content presentation	• Orderliness of transitions • Teacher's preorganization of administrative tasks • Cycles of review, testing, and feedback
6. Students' engagement in the learning process	• Use of exercises and activities to elicit student responses • Monitoring and checking during seatwork • Use of remedial or programmed materials for lower-performing
7. Student success	• Number of correct or partially correct answers • Number of right answers acknowledged or reinforced • Number of delayed corrections vs. immediate corrections
8. Students' higher thought processes and performance outcomes	• Use of teaming, pairing, or other cooperative activities that encourage student problem solving • Display of student products and projects • Opportunities for independent practice and application

Adopting these 'lenses' when observing students can determine what could be evaluated and monitored when assessing students. They can help to observe students learning and to recognise the type of evidence should be collected when measuring the learning outcomes. Furthermore, creating a virtual observation hierarchy model to determine the granularity levels of observing learning activity in collaborative virtual environments can assist designers and developers to identify the learning evidence that can be captured and help to apply it in the virtual environment. Suskie stated that 'the more evidence you collect and consider, the greater confidence you will have in your conclusions about students learning'[13].

3 Proposed Observation Technique in 3D VWs

We propose the Virtual Observation Portal (ObservePortal), which is a 3D virtual environment that can track users' behaviour and capture real-time evidence from collaborative activities. The environment employs real classroom observation lenses and applies each lens to the virtual world. The observation level can be stated in the learning design by the teacher to identify which lens should be activated to evaluate the learners. It determines the levels of granularity for observing learning activity in virtual environments to capture the learning evidence, beginning with general observation to in-depth observation (more details in section 5.4).

To capture the learning events, the platform utilises some techniques from agent systems to track users' actions and predict the learners' acquired skills and knowledge. It has two different types of agents: software agents and natural agents. The software agents track learners and collect different users' clicks and actions, while the natural agents perform peer evaluations of each other to evaluate the quality of performance. These agents are employed to record both implicit and explicit data that will be analysed to determine the learning evidence and students' performance. All agents will work together in real-time to collect the learners' evidence (more details in section 5.3).

3.1 The Learning Environment

The virtual world (ObservePortal) is the environment in which the students will perform the activities. To implement the research prototype, the InterReality Portal will be used, a project developed by a member of the Immersive Learning Lab, Anasol Pena-Rios, at the University of Essex (Figure 1) [14]. It is built upon the Unity [1] platform, a flexible development platform for assembling 2D and 3D collaborative games and environments. The environment was developed using the C# programming language. We chose to apply the prototype within this environment because it supports collaborative programming activities and assists in setting up learning tasks that help students understand the concepts and functionality of embedded systems in smart homes.

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1 https://unity3d.com/unity

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Fig. 4. Graphical User Interface (GUI) – InterReality Portal [14]

4 Conceptual Framework

Based upon the literature, observing and measuring online collaborative learning outcomes, both dynamically and on the fly, within 3D virtual worlds is scarce. As a result, we have proposed a Mixed Intelligent Virtual Observation (MIVO) conceptual framework that mixes learning models and computational models for observing and evaluating collaborative learning in 3D VWs. The framework consists of five models: user, learning, observation lenses, mixed agents and presentation (Figure 2). Each model will be discussed in the following section.

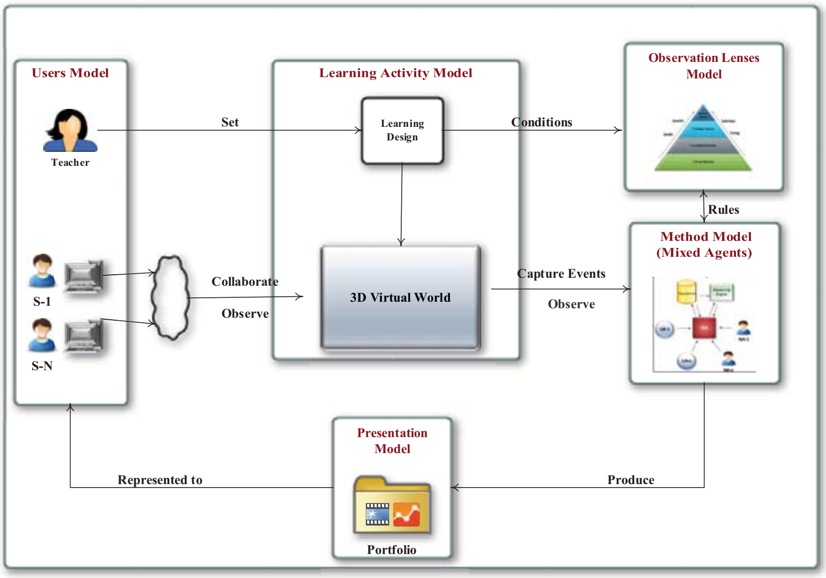

Fig. 5. Mixed **I**ntelligent **V**irtual **O**bservation (MIVO) Conceptual Framework for Collaborative Learning Environment

4.1 Users Model

This model identifies who the users are and their roles within the learning activity. Users will be either learners or teachers, and the specific user interface will be displayed based upon the user's identity and role. For example, instructors have a customisable interface that allows them to design learning activities. Moreover, a teacher can view learners' portfolios to evaluate their performances and review their work. From the learners' viewpoint, the user interface will enable them to interact with the environment and with other students' avatars. All participants will then work together on the simulation learning activities in the 3D environment. They can participate in the activities, evaluate others, obtain learning feedback from the system and view their portfolios.

4.2 Learning Activity Model

This model consists of two parts: the learning design and the environment that contains the collaborative learning practices. The learning design is defined as the learning scenarios that can be shared in the system and that can be planned and adjusted by the teachers. Moreover, the teachers can specify the observation criteria for evaluating the learning outcomes. Also, this model includes the virtual environment that students will participate in.

4.3 Mixed Agents Model (MixAgent)

This model identifies the method of gathering different types of evidence to illustrate individuals' and groups' learning outcomes. We expand the concept of software agents to include natural agents (users). The software agents will be needed to automatically track users' behaviour and collect data from real-time events as users interact with each other and with objects in the virtual world. Two types of software agents are used: user agents and ontology agent. In addition, the natural agents will be combined with them to enhance the capture of evidence. All agents, software and natural agents, will collaborate and work towards one central goal together, to produce evidence that evaluates the quality and quantity of students learning and performance (see Figure 3). In the following section, the agents' capabilities including their particular assessment abilities will be discussed.

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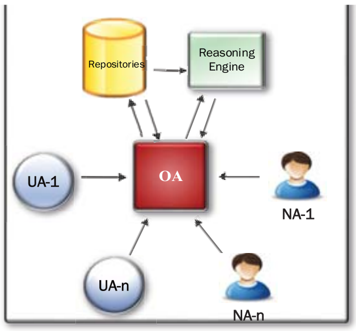

Fig. 6. Mixed Agents Model (MixAgent)

- **User Agents (UA).** These agents will be created once a student is authorised in the environment. There will be an agent for each learner. This agent can trace the user's actions in real time, translate any behaviour into data and send them to the ontology agent. They will monitor users' log data, behaviour and history.
- **Natural Agents (NA).** Peer evaluation could assist in capturing implicit learning evidence that is hard to capture with technology [8], and it would be useful to secure it from people directly to distinguish students' performance. To this end, learners will be considered natural agents. These agents can produce learning evidence by regularly assessing the quality of each other's communication, negotiation, teamwork, and active learning skills. While students are working together, there will be sliding scales scored from 1 to 5 will allow natural agents to act and rate other learners regularly. When the natural agents produce evidence and trigger the system, messages will be sent to the ontology agent. The ontology agent will receive the data and store them in the ontology repository. Employing natural agents will permit capturing the quality of learning outcomes that are too complicated to be identified by technology.
- **Ontology Agent (OA).** This agent is based on a semantic web and ontology approach that models different elements in the VW. Ontologies typically consist of object classes, the relationship between these objects and the properties that the objects have [15]. With ontologies, we can set up all the relationships between objects so that devices can understand the meaning of concepts. They can offer a standardised vocabulary to describe a knowledge domain by developing connected semantics and sets of vocabularies that can be reasoned. Thus, we have proposed this agent which has the ability to receive data from other agents and send them to the repositories. It will act as a communication agent and a bridge between all agents in the learning environment, so the collected data from other agents can be analysed based on logical rules that could assist in retrieving learning evidence. This agent will infer the relationship between the collected data and what it means in term of learning evidence through using a reasoning engine. Moreover, the logical rules will permit reasoning the repositories and parsing more meaning from the data gathered by each agent.

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4.4 Observation Lenses Model (OLens Model)

This model determines how we can analyse the data that is captured by the agents. To observe the students in the classrooms, educators should consider numerous criteria, aspects and frames to gain more insight into the students' learning and improve their education. However, not all learning outcomes and skills mentioned can be easily observed and identified in virtual environments. Depending on the observation framework [12], we adopt particular 'lenses' to our model and applied them to the 3D VW to evaluate what could be monitored in these environments. The virtual observation model defines the levels of granularity for observing students and recording evidence of collaborative learning, commencing with high-level to low-level observation (see Figure 4). The observation layers are: events detection, learning interactions, students' success and performance outcomes.

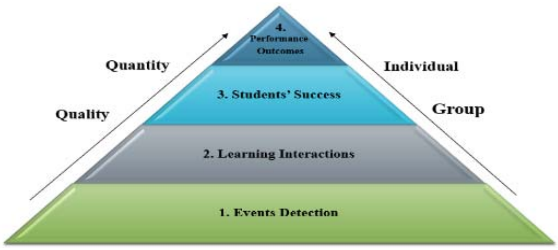

Fig. 4. Observation Lenses Model (OLens Model)

Describing the model lenses and their pedagogical meaning, beginning with the lower level of the hierarchy is Events Detection lens. This simulates an instructor when he/she watches a collaborative activity from high altitude, but without looking deeply into what is happening. In the VW, the automated observer monitors the activity by recognising that a sequence of events is occurring and capturing these events without judging. The second level is Learning Interactions lens, which considers a deeper view of the social and environmental interactions. In our case, the social interactions are between peers, and the environmental interactions are between students and the VW. Evaluating the quality and quantity of collaborations and interactions infers whether the learners have valuable interactions and if they are active learners in their groups. It determines the amount of sharing and interaction among students. The third level is the Students' Success lens. It represents teachers when they are observing the students' success by counting the number of correct answers, the number of right answers reinforced or acknowledged, and the number of delayed corrections. The fourth level is Performance Outcomes, which simulates the observer tracking the students in-depth to identify the skills and knowledge that they have acquired from the learning activities.

These frames help to measure the individual's and the group's performance, and the quality and quantity of each learning outcome. The following sections provide examples of how one can map some of the pedagogical lenses to collect evidence or to create logical rules that can be applied to the VWs.

- **Events Detection Lens.** This level focuses on observing the activity from a high level and collecting different events that demonstrate interactions between students and their surroundings. Examples of the events that can be observed and collected from students and group activities include the following:

  Avatar Actions:
  Avatar Log: <AvatarID, AvatarName, LogInTime, LogOutTime, Date, GroupNo>
  Chat Log: <AvatarID, DialogueTime, DialogueText>
  Touched Object: <AvatarID, ObjectID, ObjectName, TouchedType, Time>
  Rating: <AvatarID, RatedAvatar, RateScore, Time>

  Group Actions:
  Group Log: <GroupID, GroupMembers, StartTime, EndTime, Date>
  Group Dialogue: < GroupID, GroupDialogueText >
  GroupRating: **<**GroupID, GRateScore >

- **Learning Interactions Lens.** In this level, we are extending the teachers' judgements of group interactions in a physical setting to understand the interactions between the group and individuals in the virtual environment. It is possible to infer the quantity and the quality of the learners' interactions by creating rules based upon the teachers' viewpoints. Table 2 gives examples of the rules that can be created in this lens.

Table 4. Examples of the observation rules

	Quantity	**Quality**
Individual	The number of a learner's contributions in using the virtual objects during a period compared with other learners.	The rating scores for a student from other members in a period. 5 = Excellent; 4 = Good; 3 = Average; 2 = Fair; 1 = Poor
Group	The number of the group's contributions in the activities compared with other groups.	The average rating scores for all members in one group.

4.5 Presentation Model

The final model in the framework illustrates how evidence of the learning outcomes will be presented to teachers and learners. From the evidence gathered by agents and applied observation rules, the evaluation model will demonstrate how the performance of individuals and the groups was rated. The observation methods will allow analysing the learning outcomes from the activities and will correlate them to the learners' portfolios. These portfolios can demonstrate students' performances through any type of method, for example, it can include a feedback dashboard displaying when performance was either high or low, to allow teachers to evaluate the group as a whole and as individuals. Another example is that the performance could

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be reviewed by video snaps that map between time stamps of evidence and video recording to enhance the learning affordances of the immersive environment through visualising and reviewing the learning outcomes.

5 Conclusion and Future Work

In this paper we have introduced and described the Mixed Intelligent Virtual Observation (MIVO) conceptual framework for the collaborative learning environment. It consists of several models: user, learning activity, mixed agents, Observation Lenses (OLens), and presentation. The **MixAgent** and the OLens models play important roles to observe and recognise events that are occurring during the learning activity to evaluate the students learning.

This is a work-in-progress paper and there is much research still needed to be completed. Currently, we are commencing with the technical experimental phases to investigate the appropriate mechanism, based upon the complexity of observing and assessing learning in 3D VWs. The aforementioned collaborative environment, InterReality Portal, is used which allows students, worldwide, to participate in learning activities. In the future, the mixed-agents approach, namely, the combination of the natural agents (users) and software agents will be implemented to provide better results for collecting evidence and evaluating students. Hence, this phase will demonstrate how software agents can be combined with natural agents to improve the collection of learning evidence.

The next phase of the experimental phase will explore how to observe students' activities in the virtual world by applying methods from physical educational settings. The mixed agents approach helps observe and recognise events that are occurring during the learning activity and record them without evaluating the students. To analyse and translate these events, we will examine the frames of the OLens Model to create virtual observing rules that can infer learning outcomes in such environments.

The final experimental phase amalgamates all previous phases and explores the observation system implementation within the design of the collaborative learning activities, constructing learners' portfolios based on the evidence-gathering mechanisms, and analysing this data based upon the observation layers in the model in real-time.

Beside the experimental phases, the evaluation of our work is an essential component which is considered for the future progress. The research framework and models will be evaluated through user-based and expert-based evaluations. We are looking forward to report the results for the experimental and evaluation phases in future events and conferences.

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The 21st Century Interpreter: Exploring the use of smart-glasses for technology-augmented interpreting

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Abstract. In this 'work in progress' paper we set out the case for how smart-glasses can be used to augment and improve live Simultaneous Interpreting (SI). We do this through reviewing the relevant literature and identifying the current challenges faced by professional interpreters, such as cognitive load, memory constraints and session dynamics. Finally, we describe our experimental framework and the prototype smart-glasses based system we are building which will act as a testbed for research into the use of augmented-reality smart-glasses as an aid to interpreting. The main contributions of this paper are the review of the state of the art in interpreting technology plus the smart-glass experimental framework which act as an aid to Simultaneous Interpreting (SI). Later papers will report of other phases of our work.

Keywords: Simultaneous Interpreting, Translation, Languages, Augmented Reality, Smart Glasses, Meta, glossary-building, term extraction, multi-media learning, multitasking

1 Introduction

Interpreting is to orally translate the spoken words in language 'A' into language 'B'. Modern interpreting gained its professional status as early as the establishment of League of Nations, the forerunner to the United Nation [1], where interpreters were required to render oral languages between French and English, the two working languages of the organization.

Interpreters work in two different modes: consecutive and simultaneous. A consecutive interpreter listens to the source spoken language and renders it into the target language when the speaker stops for interpreters to deliver the messages to the listeners. A simultaneous interpreter renders the spoken language into the target language to the listeners in real-time while the speaker is delivering a speech. In this paper, we will only discuss simultaneous interpreting, as the smart-glasses will be applied to simultaneous interpreting only. Nowadays, simultaneous interpreters work in many different settings. International organizations, such as the United Nations and the European Commission, employ their own in-house interpreters, managed by a specific department (United Nationals DGACM n.d.), which oversees management of interpreting services for their on-going programme of international conferences and meetings.

Interpreting services are considered an ancillary service of the Meeting Incentives Conferences Exhibitions (MICE) industry [3]. Along with the development of MICE industry around the world [4], in order to engage multi-national participants in conferences and meetings, there is a growing need of professional interpreters. As such, there are already a large number of freelance interpreters, especially in the mega cities, providing interpreting services to international conferences, seminars and multi-language meetings.

The growing trend and demand are reflected by the university education system. In China alone, more than 100 universities have master level interpreters' education programmes. In the UK, the U.S and the European countries more and more universities provide master level interpreters' education. In order to provide a near-native working environment, universities invest large amount of funding in building interpreters' lab with a conference setting with a large conference table and delegate positions. The conference participants listen to the interpretation at the delegate positions through headsets.

2 Simultaneous interpreters' technical working environment

2.1 Inside the simultaneous interpreter's booth

The physical working environments of simultaneous interpreters are fixed and mobile booths. Simultaneous interpreters usually work in pairs in a booth (Fig.1). Each booth is set up with two user consoles (Fig. 2), which are each provided with a microphone and a headset. Interpreters listen to the source language through the headset and deliver the interpretation via the microphone at the same time. The interpreters take turns to interpret at every 20 – 30 minutes. The listeners outside booth listen to the interpretation from the wireless receivers or at the delegate positions. All the audio feeds are connected to a mixing console which is controlled by an audio-visual technician on site.

Fig. 1. Interpreters working in pair in a booth **Fig. 2.** Interpreter's console (the Interpreting Lab in the University of Essex)

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In order to maintain the quality of an interpreters' working environment, ISO - standards [5] have been established for both mobile booths and fixed booths. The European Commission [6] has also published a technical specification for booths in conference rooms. The standards and specifications require a booth technician onsite to guarantee the two-way communication in and outside the booth. Three core metrics aim to reduce unnecessary cognitive load on the interpreters' thereby improving their performance:

- The input sound quality (to provide clearer speech)
- The quietness of the booth (so interpreters can concentrate), and
- A good view of the conference/meeting proceedings.

Interpreters also bring their own technological devices such as a laptop, tablet computer and/or smart phone to booth. Such personal devices are used to (1) display session materials (i.e. agenda, presentation files) plus a self-prepared glossary and (2) facilitate searches on the Internet.

2.2 Alternative conference interpreting equipment

In recent years, alternative equipment has been used in conference venues, mainly to reduce the cost of equipment. For example, the Tourguide system with one-way communication channel is sometimes used for small scale conferences/meetings. With this system, booths, interpreters' consoles and the mixing console are not required. Audiences listen to the interpretation through wireless receivers. To have good audio reception, interpreters need to sit near the loud-speakers or near the human speakers. Though it saves the cost of equipment hiring, such a working environment can greatly affect the interpreters' performance due to uncontrollable audio input.

A recent innovation was the introduction of a mobile phone application which, together with Bluetooth, is used to transmit interpretation services to individual listeners, replacing the wired equipment [7]. Audio input and output for both interpreters and audiences are controlled by the application. The application claims to ease the job of *conference equipment manager*, not that of the interpreters, however.

2.3 Multimedia learning context at conferences/meetings

Conferences and meetings often have a theme or correlated themes. Invited speakers talk around the theme with the aid of presentation files, often in one of the two formats PowerPoints or pdf. The introduction of the theme, the speakers and the speakers' topics are presented on the conference/meeting agenda. The purposes of conferences and meetings are to disseminate information and exchange ideas. The process of dissemination and interaction is actually a learning process for the participants. Therefore, interpreters work not just across different subject knowledge, topics and cultures but also in different learning contexts. Recent years have seen large advances in the provision of technological support for conferences and meetings.

Compared with 20 years ago, conference speakers no longer use transparent plastic slides but instead use computer based presentation files, large rich multimedia displays (i.e. screen panels), fancy lighting, and more reliable and clearer sound systems help to enhance the multimedia learning experience of the conference/meeting participants.

Along with the development of software and applications, it becomes much easier and faster to design and create graphical information. Presenters add audio and video clips, complex diagrams, and figures to their presentations for better demonstration and explanation and to compress complex ideas within their presentations. The multimedia display of information and the more complex content in a presentation constitute a "*multimedia cognitive load*" for interpreters [8]. The implication is that while comprehending the presenter's messages in real-time as well as delivering it in the another language, interpreters will have to make use of much or all of the limited capacity of their working memory to comprehend, process and express the message in another language. There will be very little capacity left for interpreters to follow up the presenter-designed learning process for audiences.

To facilitate comprehension of a particular presentation, interpreters study the text and diagrams on slides to form understanding of the speaker's presentation and main ideas prior to the conference/meeting. In order to accurately render the speech and maintain a good flow of delivery, good views of the presentation file and the conference proceedings are essential for interpreters in the booth at the conference/meeting.

3 The role of the glossary for simultaneous interpreters

While preparing for an interpreting task, an interpreter usually compiles a bilingual glossary, which is formatted as two parallel columns, with one column presenting language-A and the other the equivalent word or phrase in language-B. The glossary usually contains unfamiliar words, technical terms and proper names extracted from *the speakers' presentation files, conference/meeting agenda and relevant readings* during the preparation phase. Professional interpreters, including the interpreters from the Association Internationale des Interprètes de Conférence (International Association of Conference Interpreters AIIC), consider glossaries to be of paramount importance.

AIIC is a global association of conference interpreters with over 3,000 professional members from across the world. The organization was established more than 60 years ago. Their web magazine regularly publishes articles about hot issues in the interpreting world, glossaries being one of the popular topics. The association has given guidance on glossary building in their *Practical Guide for Professional Conference Interpreters* [9]. This guide suggests the process of glossary building is a learning process which helps the interpreter to understand and remember terminologies and concepts.

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A recent article in AIIC [10] presented the results of "*A survey of glossary practice of conference interpreters*". The results confirmed the importance of the learning process during glossary building, describing the process as one to "*learn about issues and concepts*". In the survey, professionals agreed that most of the glossary comes from presentations, the agenda and information linked to the agenda [10]. Moreover, the survey indicated that instantaneously retrieving the glossary from (1) the interpreter's memory or (2) a glossary list, are the only ways to use the prepared terms in the process of real-time rendition and delivery. This survey, not only emphasized the significance of the glossary list, the presentations, the agenda and interpreter's memory, but also illustrated a dynamic relationship and links between them.

3.1 Technologies for extracting terms and build up glossary

The ways to search for accurate translations of terminologies and proper names have changed from using traditional dictionaries to online dictionaries, and/or massive cloud services and databases [11, 12]. Xu and Sharoff [13] reviewed methods using comparable corpora to extract terminologies from conference documents and web content. They claim when the accuracy of the generated term lists is high, the use of automatic term lists could improve the preparation efficiency of interpreters.

More applications are also available to interpreters. Costa et-al [14] reviewed the available software for interpreter's terminology management to be used prior to an interpreting task. They also described "unit conversion" applications for mobile phones which are helpful when converting between currencies and measuring units.

3.2 Are technologies assisting interpreters in the right way?

This is a serious question raised by researchers and practicing interpreters [12, 15]. Technologies can be helpful, but with conditions and constraints. Various issues raised include how much time interpreters might spend on finding the resources and trainings required to learn and adapt to the new technologies, the familiarity required to use the new technologies, and the cognitive capacity available when working for using these technologies. For example, when an interpreter works in the booth, with a laptop to read the slides, a tablet showing terminologies, and a mobile phone at hand ready for looking up new terms, the interpreter will have to shift attention and increase processing capacity when using different media to search for information.

4 Challenges to Interpreters

4.1 Cognitive challenges

Cognitive challenges are also widely acknowledged and discussed theoretically by researchers and practicing interpreters. The last two decades has seen considerable discussions concerning the cognitive challenges faced by interpreters, firstly from a linguistic perspective [16–19], and secondly from a psychological perspective [20–22].

This research has shown that modern presenting methods and rich-media contexts bring additional cognitive challenges, the extent of which are dependent on the content in the presentation files and on the nature of the technological environments.

Brook Macnamara [23] from Princeton University reviewed all the cognitive aptitudes required of an interpreter, and identified the cognitive functions required for interpreting. She used five complex diagrams to illustrate the required skills, abilities, intelligence, and memory from "operational, perspicacity, processing, and second language learning" perspectives (see Macnamara's paper for details), which in turn evidently reflects the cognitive challenges often experienced in interpreting.

4.2 Multitasking, attentional control and memory

Simultaneity of cognitive tasks (listening, processing and speaking) is known as multi-tasking, which is a foundational skill of Simultaneous Interpreting (SI). Attentional control allows interpreters to appropriately allocate attentional resources: (1) to attend to the useful stimuli to "logically reason, analyse and store information in memory", (2) to activate a functional working memory for processing information and form renditions in the target language [23]. With the additions of presentation files, the use of glossary list and other conference/meeting materials, the interpreters also need to allocate attentions to visual aids so as to assist comprehension and rendition. Technological advances in the personal devices are intended to support the interpreters with better management and easy alignment of additional visual information. However, the diversified applications and formats of the conference materials require the interpreter to allocate cognitive capacity and shift attentional resources for managing and processing different visual materials. For example, in a case when an interpreter needs to find a term in the glossary (prepared from the presentation materials), the interpreter's attention shifts to finding the term in the long list of glossary.

As suggested by Macnamara [23], in the process of simultaneous interpreting, attention is allocated to different tasks simultaneously. Familiarity of tasks reduce cognitive load. The extreme development of familiarity is automation (as cited in [23]). In the previous case of 'term searching' in the glossary, an automated search for terms in the glossary illustrates one form of automation. Later in this paper we will present a system (hypothesis) which explores both opportunities for reducing cognitive load through use of automation and a better designed Human Computer Interaction (HCI).

4.3 Challenges caused by the location of booth

We will illustrate the challenges facing interpreters by studying one of the settings of our training facilities in the University of Essex. LTB6 (Lecture Theatre for teaching) in the University of Essex was built with fixed booths. This facility is used to host mock conferences to train interpreters. The venue comprises a large lecture room with

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a capacity for 300 people. The booths are fixed on one side of the upper floor (see Fig. 5).

When the interpreters go into the booths to setup the workstation, they turn on a laptop which displays a glossary list together with the speakers' presentation. In this particular context, the interpreters need to constantly check the main auditorium screen to follow the presenter's speech. As the screen concerned is about 30 meters' to one side of the booth (Fig. 3 and Fig. 5), the interpreters have difficulty reading text on the screen. To have a view of the conference proceeding, the interpreters need switch their gaze from the main auditorium to their personal laptop from time to time. Another difficulty is that the interpreter is not always able to realize immediately when the presenter changes slides, especially when the display on the projector is unclear (Fig. 4). In cases where speaker's jump slides, there is a risk of negative psychological effects on interpreters who feel they have lost track of the presentation.

Fig 3. Interpreter looks at the projecter from booth

Fig 4. Projector's view from booth

Fig 5. Booth position in LTB6

The pre-prepared glossary list can have thirty (or more) pairs of specialized terms in two languages. When the presenter mentions a term which was included in the prepared list but which the interpreter cannot remember the exact translation of, she/he needs to refer to the glossary list. Finding the term from the glossary list means re-focusing their attention away from the speaker and the list (adding to their cognitive load), until the term is located. In a case when multiple unremembered terms appear within one sentence, the interpreter needs to find all of them from the glossary list, occupying a great amount of the interpreter's cognitive capability and risking delays in interpreting.

Thus, from this setting we argue that cognitive loading (or overloading!) of an interpreter is a major factor in determining how well an interpreter performs. In particular, for any technology to be adopted by interpreters it needs to lower, rather than increase their cognitive load. The two most important aspects of cognitive loading for interpreters is 1) their working memory, and 2) their speed of reasoning. The first of these can be supported by creating computer supported glossaries of terms, with fast search methods to access them (essential extending working memory) and the second of these can be improved by good human-computer interaction design making information and control simple and intuitive (essentially simplifying any reasoning activities). By way of a theoretical basis, for the first we are building on the concept of working memory, for the second we build on the notion of elementary mental discriminations, or the Stroud number. Exploring how technology, and in particular smart-glasses, could positively augment an interpreter's capability is the aim of our research. Our approach to this is described in the following section

5 Interpreting in booth with augmented reality glasses

Fig 6. Chantel (interpreter) in a booth **Fig 7**. Chantel (interpreter) wearing meta-1 glasses

As was explained in the previous section, we have set out to explore how smart glasses may be used to reduce the cognitive load on interpreters, in order to improve their performance. Thus, a project was initiated in the University of Essex to undertake research on potential solutions to the challenges described in the previous section for 21st century interpreters using augmented reality smart-glasses. At this stage we are hypothesising that smart-glasses can overcome the problems we have described, so our mission is to characterize the challenge (one of the purposes of this paper), create some theoretical models for the pedagogy and computer architecture (another aim of this paper) and then finally test the hypothesis by experimenting with a real system (an aim of a future paper). Our hypothesis is not simply a binary question (does it hold or not) but rather an exploration of the variables at work especially regarding HCI parameters such as size, position, colour and mode of control of the interpreting session data. Thus our experimental architecture seeks to accommodate as much customisation as possible, allowing the interpreters to change as much of the appearance and operation of the system as is practical. Explaining this in another way, we are arguing that by placing a pre-prepared glossary, together with other session information in the interpreter's field of view (Fig. 8) using augmented reality glasses (with appropriately designed Human Computer Interaction), interpreters will be able to reduce their cognitive effort and concentrate more on rendering information and messages from different sources.

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At this stage we are prototyping the system, starting with an electronic mock-up of the user interface which is shown in the diagram below:

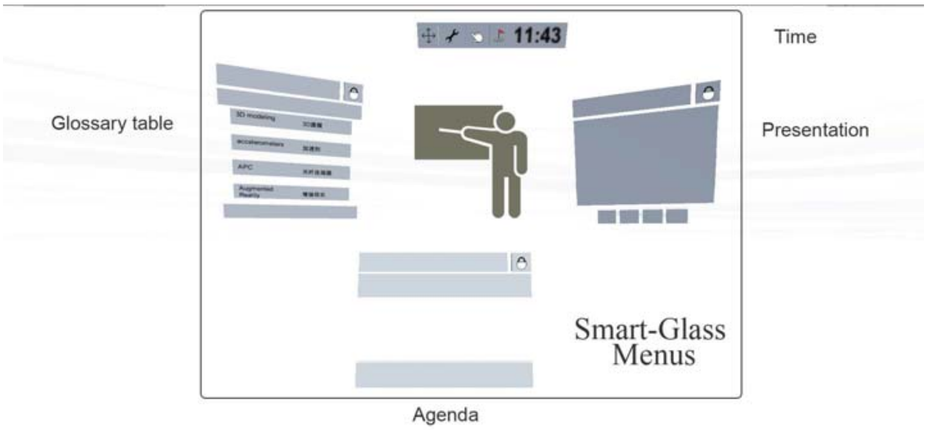

Fig 8. AR-Language Interpreting smart-glasses screen

We envisage the smart-glasses will be worn by the interpreters during live sessions allowing them to simultaneously view the real event and virtual screens containing supplementary materials positioned to one side of their field of view. The virtual screens are relatively large (a metre or so at a distance of a few meters) and contain information such as the glossary of terms, the agenda, the presenters' slides, the time and an auxiliary window that could, for example, be used by the supporting (second) interpreter who could provide additional and unplanned information. We also envisage that the second interpreter would wear a set of smart-glasses which they could use to manipulate information at key moments; to assist the main interpreter (eg undertake an online search for unknown vocabulary arising from a Q&A with the audience). This is very much an experimental system, and so one of its purposes is to allow the interpreter to customize the environment as much as possible so new research data can be gathered from how the system is personalized or used in live interpreting sessions. Thus there are many hidden functionalities concerned with personalizing the environment.

This framework forms a model for interpreting that we call SmARTI (Smart Augmented Reality Technology for Interpreters). The Meta glasses we are using were designed for individuals to wear, but have proved to be little heavy for prolonged use. Thus, one of the ideal specs for of smart-glasses for interpreters would be lightness; other features being no wires (not tethered), fashionable appearance, excellent sound, long battery life (at least a half day) etc. The current state-of-the-art in wearable AR glasses has some way to go before they would meet an ideal specification for interpreters since they are tethered, a little on the heavy side for prolonged use, and the geeky appearance might not be appealing to all interpreters! To popularize the use of this technology, interpreters will require further hardware improvements which this work will also aim to throw light on.

6 Summary & Reflections

This paper introduced the booth environment for simultaneous interpreters. It argued that insufficient assistance is given to the interpreters in booths to reduce the cognitive load caused by the increasing use of technology and the ever-increasing complexity of contexts at conferences and meetings. In particular, we identified that extending working memory and easing reasoning tasks were key areas where technology might be used to improve an interpreter's performance. We also proposed that wearable smart-glasses might provide a useful simultaneous interpreting environment and, have described some preliminary studies we are undertaking using Meta-1 augmented-reality glasses. This is a work-in-progress project and at this stage we have framed the problem space through a literature review, identified the research issues to be explored, proposed a solution (with hypothesis), created an operational model (SmARTI – Smart Augmented Reality Technology for Interpreters) and built a simple prototype all of which we have reported on in this paper. Our longer-term aim is that we hope to be able to create what is, in effect, a virtual (and wearable) interpreting booth that is designed in such a way as to reduce the cognitive load on interpreters, thereby improving their mobility and performance. Our aim is to refine this design through ongoing work, further exploring the issues and reporting on those at later conferences.

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Mind, the Gap

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Abstract. Training is needed to exercise our most important organ: the brain, exploit its full potential and sustain it for our later years. Does a gap exist in our capacity for learning, a gap between what our brain could potentially achieve and what we are currently prepared to accept? The 'prototype' follows an ambitious undergraduate Computer Science student as he gets drawn into psychophysiological experiments that explore brain-training, involving image recognition, cognition, subliminal delivery, and imagined movement. Such technology has great potential for promoting and assessing learning and possibly exploring under performance or dysfunctional learning. However, as with all technology that enhances the human, there is potential for unintended use that we should be mindful of.

Keywords: Brain computer interface · Immersion · Stimulation · Brain-training · Enhancement · Subliminal learning · Brain-washing

1 Introduction

Our mind is our intellect, our ability to think and reason. In his book exploring the human mind, Professor Robert Winston [1] states, "*With the help of science we can now begin to understand the extraordinary complexity of the brain's circuits: we can see which nerve cells generate electricity as we fall in love, tell a lie or dream of a lottery win. And inside the 100 billion cells of this rubbery network is something remarkable: you.*" However, eminent neurosurgeon, Henry Marsh recently stated that we understand more about the universe than our own consciousness [2]. As scientists and educators, we need to further understand the mind and its underlying hardware, the brain. If we do not train our bodies, then such neglect is obvious by sight; quantified by metrics, such as body mass index. Labels to describe poor conditioning are in everyday use: sedentary, obese; this has led to new terms in our vocabulary such as 'diabesity'. But what happens if we neglect our brain, if we under-stimulate the mind. At the developmental stage (i.e. early years and school) will the brain ever reach its full potential? Peer judgement on intellect is less obvious but 'measures' such as Intelligent Quotient (IQ) and examination grades are widely used by society and subsequent labels can be harsh and detrimental to the individual. If a person fails to achieve a pass in an examination then there may be many contributing factors beyond intelligence: motivation, appropriate learning and teaching, even social class and proper nutrition. And what of people with special educational needs, such as Attention Deficit Syndrome (ADS) or dyslexia? Such needs often go undiagnosed leading to inappropriate teaching

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environment and support. As we mature into adulthood then surely we can achieve even more if we continue to stimulate and train our brains. How does advancing age affect our intellectual abilities: can brain-training reduce the incidence of forgetfulness, cognitive decline, even the onset of dementia? These are significant societal questions as the ageing demographic rises.

But how can we measure learning in real-time? This paper investigates the possibilities of brain computer interface (BCI) technology [3] for image identification and extrapolates this to learning[1]. It takes the viewpoint that the brain is under-utilized and would benefit from increased stimulation, in an immersive environment. However to be beneficial, we need to measure and quantify changes in brain activity. Visual Evoked Potentials (VEP) [4] and Cognitive Event-Related Potentials (ERP) [5] can be measured in neurophysiology laboratories. Could this technology be translated into mainstream learning in the future, to human enhancement? The public is equally fascinated and suspicious of emerging technology. This is particularly true of BCI devices, which are seen as clinical and invasive, the stuff of medicine or even science fiction [6]. One well-known myth of BCI is that it can be used for 'brain-washing'. *Or is it a myth?* This prototype addresses BCI for learning application in immersive education. Adoption of such technology could throw up unanticipated consequences. Technology such as Oculus Rift can provide appealing and stimulating immersive environments; eye-tracking can provide an objective measure of eye gaze on a computer screen; combined this powerful technology can be linked to user engagement. But there is a gap, how do we as teachers know that a student has *really* understood a topic? We should mind the gap.

2 Rationale for a Prototype

The fictional work is motivated by the mystical lyrics of the 1971 David Bowie song, *Quicksand* [7]. The 2016 release of the his last record *Blackstar* and accompanying videos[2], featuring a preacher and his 'blind' followers, reignited interest in Bowie's fascination with the occult (evidenced in his *Station to Station* album, 1976), magician Aleister Crowley and the Golden Dawn cult [8, 9]. The visual imagery was particularly poignant, as it provided many subliminal indicators to Bowie's imminent death, which duly occurred on 10th January 2016, 2 days after the album release. So this prototype is an investigation of BCI and learning; homage to a *guy that's been*. It weaves a make believe web, linking characters: Crowley (a persona projected onto the research Psychologist), poet W.B. Yeats and renaissance artist Michelangelo[3], all with reported interests in mysticism and cults. The prototype blurs what is currently possible with BCI technology; crossing the line from the human being in control, through to shared autonomy and to eventual brain-washing, with human subservient.

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[1] This step takes us beyond the current state-of-the-art, into the realms of sci-fi prototype.

[2] Two controversial videos, "Blackstar" and "Lazarus" were recorded as Bowie contemplated his final act, whilst battling liver cancer.

[3] Yeats referred to Michael Angelo [misspelt] in his poem, *Under Ben Bulben.*

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There are many gaps. The title of this paper refers to the ‘gap’ between what a human brain and mind can currently achieve and what maybe possible. However it could also refer to the gap that neuroscience currently has in understanding the complex brain, the scientific gap in our knowledge.

3 Fictional Story – The Golden Dawn Experiment

“Mind the gap”[4]. I’m on the subway in London waiting for a tube. “Mind the gap”. I’m headed for the *Villa*. I’m not sure whether the journey will end in enlightenment or oblivion. The tube arrives. “Mind the gap”.

> *“I’m closer to the Golden Dawn,*
> *Immersed in Crowley’s uniform of imagery”* [7]

3.1 Cats and Dogs in the Psychophysiology Laboratory

{A few days earlier}

“This is the future of education?” I pondered as I made my way to the Psychology Department. I had replied to an intriguing email from an organisation called, ‘ORMEN: Operations and Research for Mental Enhancement Network’. It sought student volunteers to take part in a pedagogy experiment called ‘Golden Dawn’. I had finished my exams at last and had time on my hands. The information provided was not very specific:

> *The focus of this special track will be to explore the possible ways immersive-reality technology might change future education.*

I had achieved good grades in my Computing degree so far and I was particularly interested in research into human computer interaction, so I fulfilled the inclusion criteria. I was also interested in the fee of £10 per hour-long session, which would definitely be worth it, if I was selected for continued participation throughout the day. On arrival, I filled in some run of the mill ‘consent’ paperwork, which I probably should have read more closely and found myself in a laboratory with a couple of dozen others, presumably like-minded cash-poor undergraduates.

I was seated in front of a computer, with a keyboard, mouse and a set of virtual reality (VR) glasses, under starters orders. An announcement was made on the screen. “`You will see some images on the screen. All you have to do is count the number cats and dogs. Ignore the other images`”. The screen flickered into life in front of me. Images were presented sequentially. Each time a dog or cat appeared, I pressed left or right mouse button as appropriate, and as fast as I could. It was easy, not much to this Psychology at all, I thought. After about thirty minutes the experiment ended and a message on the screen appeared that I could proceed; I should continue to be seated. There was the movement of chairs and some

[4] 'Mind the gap' is an audible warning provided on London’s tube network and railway stations. Announcer Phil Sayer died in April 2016, aged 62.

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people left the lab, presumably they had difficulty distinguishing a cat from a walrus, a dog from a duck, either this or they were happy with their tenner and were heading to the pub for lunch.

A further announcement: “`This is an immersive test. Put on the glasses. You will see some interesting images. All you have to do is count the number cats and dogs`”. I was always a ‘techie’, so this really appealed. The glasses flickered into life and the cats, dogs and other strange creatures, some mystical, again appeared, but this time in glorious 3D. I felt a bit disorientated as bizarre lifeforms flew past me, and lingered behind, above and below. A few more targets were visible to me in the periphery of my vision, and with the VR I could *turn and face the ‘strange’*; the count went up. I was dizzy and probably needed a glass of water, but somehow I felt I couldn’t ask for one. At the end of this session, I was again successful. It was just like being on The Krypton Factor[5], I thought. A few sighs from around the room and the number of participants was again reduced.

A third session followed, this time in the dark, pitch black and eerie. Fainter images were interspersed with the brighter easier identified targets. They must have been there all the time, and I hadn’t spotted them. There is something to this Psychology.

> *“I’m torn between the light and dark*
> *Where others see their targets in divine symmetry”* [7]

Still I was retained in the diminishing group of participants. In the next session, the speed of delivery was increased. Was that a cat? I thought I saw 10 dogs or was it 11? Maybe there were a few I missed? Now my mind was working overtime. A bit surprised this time, as I again got successful feedback. This brought us to lunchtime; a free lunch, yet another bonus.

At lunch I was directed to a table with four other ‘select’ participants and our tutor, a Dr. Crowley. She put us at ease straightaway, and praised us for our vision and quick reactions. We were disarmed. We discussed the motivation for volunteering. The others were definitely motivated by research, as of course was I (although in truth, I was feeling a bit out of my depth). We were asked about our interests. With the others responses were quite high-brow, art and poetry; for me it was seventies pop music and David Bowie in particular. “Interesting”, posed Crowley. “That’s my era, seems too dated for you”. “I got into Bowie, from my mother’s old vinyl collection. It keeps my memories of her alive”, I said. “Interesting” was again the sparse comment. She was probably a fan, I thought. Crowley informed us that we were the top performing participants. She suggested that we could continue with this mundane pedagogy work in the afternoon or undertake some ‘real’ research. Of course this was like a red rag to a bull. Perhaps we had already been psychologically profiled, I pondered. Swept along by ego, I plumped for the real research. That made five of us.

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[5] The Krypton Factor was a ‘serious’ game show in the UK which pitted contestants in physical and mental challenges.

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3.2 A Sublime Afternoon

We were directed down a labyrinth of corridors to a smaller electrophysiology suite in the bowels of the building. The rest of the participants went back to the original lab to 'play' with the computer gadgets. Our group was then prepared for the afternoon experiments, which involved the acquisition of our 'select' brain electrical activity in response to visual stimulation. I had read articles on this type of Brain Computer Interface (BCI) experiment [10]. This was exciting work, at the forefront of Computing and it could be a real benefit to humanity. People who had peripheral neural dysfunction or 'locked-in' syndrome could benefit from it as an assistive technology. This was Psychology and Computer Science in sweet harmony. I was definitively in the right group, with the elite. Instead of pressing a button to signify a response, the researchers could study my brain patterns in real time to check my brain's response to the visual stimuli. Crowley had a couple of lab assistants. They expertly applied electrodes to our scalps. After a little bit of tweaking, a bit of scraping and a tiny bit of boring, which provided some mild discomfort, and a fair bit of hair gel, we were ready. I enquired about the paperwork for this research, but I was reassured that I had already given my consent in the morning. I couldn't recall this bit but hey, this was real research.

A familiar announcement was made. "`This is an immersive test. Put on the glasses. You will see some images. All you have to do is count the number cats and dogs. We will do the rest`". The lights went down and my anticipation rose. Then…what a let-down! The same images were presented, cats, dogs and an array of animals some real, others mystical, some bright, others faint. What was worse, for the next two hours we had to endure three more sessions, some presented faster, others slower, but an overdose of feline and canine targets. At about 4 pm it was over. The helpers took off the electrodes. My scalp stung due to the alcohol solution that dissolved the electrode gel, and my brain hurt through overuse. I was disoriented, practically seeing stars. Well that should be about £80, not bad for a day's work, I consoled myself. I assumed that we would be leaving, then but there was one more session - a test. I had overdosed on exams already.

3.3 Testing Times

We five donned the goggles again. Our instructions were familiar. "`You will see multiple choice questions. All you have to do is choose a, b, c, or d on the keyboard`". An image flashed. It was Irish Nobel laureate, William Butler Yeats. I identified him correctly, most people would. Second question: Where was Yeats born? I quickly answered, *c: Sandymount in Dublin*, although I'm pretty sure it was Sligo. Where did Yeats study? I answered, *a: Erasmus Smith High School*, completely guessing now. Oh dear!, I never really studied poetry at school. Questions continued: Complete the verse: *We rode in sorrow, with strong hounds three*. I choose option, *d: Bran, Sceolan, and Lomair*. In all I answered 20 questions, and then time was up.

We then awaited feedback from Crowley and we all hoped that the test results wouldn't influence our payment, in any way. Results from the tests; we had ALL scored either 19 or 20 out of 20. I looked around puzzled, at my colleagues. They all

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must be from the English department, studying poetry, I thought. I offered some explanation to my tutor. "Lucky guesses by me, I said". But Crowley retorted, "PJ, can you finish this poem?

"Proof That There's a purpose set
Before the secret working mind:…."

"…*Profane perfection of mankind;*" [11], I replied, before I could even think. I was facing the *strange* indeed, it couldn't be a guess. "You're an expert on W.B. Yeats", she said. I liked being called an expert, but I was now definitely in some surreal zone, head spinning, not really sure what was happening. Crowley continued to the group, "You will receive payment as you leave. I would like you all to come to a session tomorrow. Remuneration will again be provided. Can you make it?" My four colleagues confirmed straight away, as did I, actually before giving it any thought. But another £80 in the bank was all to the good.

On my way back to my apartment, my head was filled with the poetry of Yeats. Funny, thoughts of computing, science or old seventies tunes normally swirled through my brain. Today, I knew everything Yeats, but how? After some rest and gathering of my wits, I guessed that I was in the middle of some sort of subliminal study. I wanted to ask some probing questions about this, but I felt inhibited. And why didn't the others ask, anyway?

3.4 The Next Day: Michelangelo

The next day followed a similar a pattern. This time we five elite were looking for *daffodils* and *roses*, but I soon realized that this was totally unimportant. After a day of electrophysiological recording, we were tested again. I had developed significant expertise in the art of Michelangelo; works, many with subliminal meaning that I could readily identify during the end of day test. I was able to confirm that the depiction on the ceiling of the Sistine Chapel of *The creation of Adam* provided an anatomical illustration of the human brain in cross-section; *Separation of Light from Darkness* gave a ventral view of the brainstem [12]. Then we all received another invitation for day three.

Firstly, expertise on W.B. Yeats and then an appreciation of the works of Michelangelo: not bad for a Computing second year. I revised my television quiz aspiration upwards to *Mastermind*[6] contestant; I'll take Yeats in the first round and Michelangelo in the semi-final, I mused. This subliminal learning was powerful stuff. Should I persist or should I question it? Would I be removed from the study and relinquish the easy money? But my thirst for this easy knowledge was also growing more powerful. I could be an expert on composers, artists, potentially anything. Computing next please, I thought. Imagine, final year would be a breeze; no late nights, no popping pills to stay awake and enhance brain-power.

[6] Mastermind is the regarded as one of the more demanding television quizzes, usually for the more esoteric and intellectual.

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Day three, and I didn't have to ask. When we arrived Crowley was there to brief us. "We have a new 'network' experiment, cutting edge research this time", she stated. "I guess you are all wondering what's going on". After a pause, to check our complete acquiescence with the process, she continued, but this time with much more passion and feeling. "The brain is very powerful, it takes up 20 % of the body's energy resource. It can process 11 million bits of information each second. But most people use less than 10 % of its capacity. Our research, the Golden Dawn project, is addressing this shortcoming. If we all use even 50 % of our brain-power, humanity will enter a renaissance, a golden dawn of enlightenment. We will reach a higher level of wisdom, people with less able brains can be identified, and defects rectified. We can discover the genes responsible for intelligence." After a pause, she calmed a bit. "As you may have deduced we have been stimulating your brains with images that are not readily perceptible to you. We know the response of your brain to an image you are searching for. We know that you have searched for it because we have monitored your gaze with the glasses. We know much about your interaction in the Golden Dawn experiment. If we get this same response to an image that you haven't looked at, we know that your brain has detected it, but you probably are unaware that you have seen it; the image may have been too faint or may have been too fast. All the same, because of the untapped power of the brain, you have still noticed it and can recall it."

"But why…", I thought to interrupt. Crowley pre-empted, "You haven't asked questions because in the experiments, we keep telling you not to, it's a frequent stimulus you don't perceive – we call it the *Don't Ask* stimulus! It's in the form of a white star" No need for me to finish then. "Your brain can detect an image long before you can press a button. You five have the most reliable visual perception. But sometimes, even one of you will miss a stimulus. This is unacceptable if we are to capture the knowledge". "We need volunteers for the next study. Who's in?" We all said "yes". Did we have any choice? I guessed there was probably a *Say Yes* stimulus too. I didn't ask.

3.5 Big Lou – A 'Real' Brain Neural Network

My appetite for knowledge was becoming more powerful; it was a drug. Crowley was right, think of what we could achieve, and we five were in the vanguard, we could become 'versatilists' of all knowledge. The next day, we were prepared as normal, nothing new. The experiments started again. This time I identified targets of colourful "fish" and cuddly "rabbits". But what would I learn? What would be the real test? I sought more expertise.

When I took the test, I realized that we were subconsciously straying into somewhat uncomfortable territory, immersed in a genre of violent video games. I was now identifying future crime scenes and potential perpetrators. This wasn't *Finding Nemo* meets *Bright Eyes*; it was *War Games* meets *Minority Report*. And something new was happening in the controlling computer. The potentials from our brains had been joined together by an Artificial Neural Network into a fuzzy decision-making brain network, linked to a cognitive computer called 'Big Lou'. If I didn't identify a scene, then one of my colleagues almost certainly did. This increased the reliability of ensemble identification to 100 %, and then I was then re-trained to rectify the error. This was indeed a

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powerful network for decision making, tapping into the brain's unused potential, into a network of brains. And we could learn from each other to perfect learning strategies. The potential for this intelligent cognitive computer was enormous.

At the end of this session, Crowley called me aside. "PJ, you are the best of the group and you have learned even more from the other four. You no longer need them. You can proceed beyond research. *Operations* Golden Dawn needs you. You have been selected for the next phase. It is located in the *Villa* in London. You will meet my colleague, Tom. Will you go?" I wanted to ask what the operations were, what the villa was for, but I couldn't. I should have stopped then, but I couldn't. I needed to learn more. All the information derived from the study would be used for good to help people enhance their learning, wouldn't it? "Yes", I said. Of course I did.

3.6 A Spider's Web in the Villa of Ormen

I had been given a plane ticket to London Heathrow, further directions and a letter of introduction, by Crowley. I travelled on the underground tube on the Piccadilly line to Gloucester Road and then the District line to Temple. "Mind the gap, mind the gap". I could hardly wait. I was driven for new knowledge, my mind now possessed by some thirsty demon as I progressed from station to station. Eventually I arrived at my destination, somewhere near Blackfriars Bridge. I looked for a sign for 'Operation and Research for Mental Enhancement Network', but there was nothing, a cloak of secrecy. The building was old, built in gothic style, very atmospheric.

A doorman, possibly a security guard, checked my letter of introduction and I was ushered in to a dark corridor illuminated by a solitary candle. I met Crowley's colleague, who introduced himself as Tom. He was evidently a military type, loud, quite pleasant but not to be messed with. "Call me Major", he said. I was informed that I was here for my inaugural competition, which would begin in the morning. I would need rest, as this 'track' would be mentally tiring; I would be staying on the premises. The building was eerie, silent save for the hum of vespers or chanting. I guessed there could be a religious service in an adjoining room or maybe the sound could have been in my head. I couldn't really tell anymore.

In the morning after breakfast with the Major and three colleagues, I was briefed on the purpose of the track, which would be held in a CAVE. A number of candidates were being 'interviewed' to join the Golden Dawn elite; I was effectively in a play-off, with others from around the globe. There would be only one recruit, the others would be eliminated; their journey would be at an end. I now realised I was really in a nerdy version of *X-factor*[7]. I found out that the CAVE was a Computer Assisted Virtual Environment, a distributed, interactive games venue. The Villa housed the UK's node. There was a global labyrinth of CAVES, all connected to 'Big Lou'. Instead of putting on a VR headset and experiencing an environment in 3D, I was in it! The electrodes were again expertly applied to my scalp. This time I also donned a smart shirt, with

[7] X-Factor is an entertainment show requiring considerably less intellectual ability, but possibly a modicum of singing talent.

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sensors and actuators to measure heart rate and galvanic skin response, and constrict upon command.

The Major was the BCI expert, he instructed me in imagined movement [13], whereby simply the thought of moving a finger would enact a motor response, a ‘trigger’ potential. He told me that each time there was a shoot-out, the candidate with the slower trigger would feel a sharp tightening in his chest. The feedback was realistic, important for motivation. Each Golden Dawn candidate had three lives. Anyone losing a third life would be eliminated.

I entered my CAVE pod. `This is an immersive test. You will see some images of assailants. All you have to do is identify them and use your trigger to eliminate them. We will do the rest`”. I was in the middle of something resembling *Call of Duty*, engulfed by swarms of strange assailants but four were familiar; the Major and his band of brothers in avatar form. Presumably I was visible to them as well, in this vast virtual world. The other assailants were easily dealt with; their reaction times couldn’t match my brain’s neural response and reaction. In the end only five remained, four against me. I spotted the Major hiding by a boulder, he hadn’t seen me. I knew I could take him out if I acted fast.

Then from the CAVE’s audio came the strumming of familiar chords of a guitar. I became distracted. A familiar song consumed all my thoughts. I smiled momentarily. *“Oh Man! Look at those cavemen go. It’s the freakiest show”*. Vivid memories took over. I could visualise my hero, the *Starman* arm in arm with Ronno, singing on *Top of the Pops*, glitter, make-up and knee length boots; and he was pointing at me. I moved closer. Only then could I see that it was really the Major in disguise and he was pointing a laser weapon, not his finger. I had been tricked. It was a brain-to-brain shoot-out, but my trigger potential wouldn’t work. My chest tightened, and I struggled for breath, convulsing zombie-like.

Minutes later, I re-spawned. The computer knows I like David Bowie. I won’t fall for Big Lou’s tricks next time. But I was now in a new augmented reality, a psychedelic planet of wonderful colours; it must be Mars. Combat renewed. This time space creatures attacked, spider-like in appearance. After a prolonged bout of seventies-style ‘Space Invaders’ that I easily won, it was down to me versus the Major and his band. I was drained and disorientated when someone else entered the game. The image and voice were unmistakable to me; I could see my mother walking along an arid landscape arguing with a drugged-up clown and his followers. She had come to help me. She had always put my education first and nurtured my love of music. I needed to say “Hello”, to say “Thanks”. Up close, and then I realised that it wasn’t my mother, it couldn’t be, she had morphed back into one of the band. Distracted, I had been hit from behind. Duped again, I waited for the smart shirt to take its toll. The constriction was longer and painful, I didn’t know if I would make it, breathing was laboured, my heart rate fell; this was pretty real. Eventually the constriction eased and Lazarus-like I was back in the CAVE. By now I was mentally exhausted, the demon within all but gone. I knew the next contest would be my last. I couldn’t match the cognitive computer.

I didn’t have to wait long. I was transported back to a virtual Villa of Ormen. I heard the faint murmur of chanting, just as I had heard the previous night. I could see the blind followers, convulsing in unison to the chants. I didn’t want to join this strange band of thought-controlled brothers. I wanted knowledge but there is no free lunch.

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I left the safety of the villa and ventured outside, prepared to take on whatever strange elements this planet could throw at me. This time I was not pitted against alien creatures but fast moving colliding geometric shapes; pentagrams, hexagrams and 12-pointed stars that whizzed by in 3D, like a scene from Star Wars. White stars with *Don't Ask* and *Say Yes* messages abounded, frequent indeed. I needed to navigate right, left, up or down to avoid them and survive. This was more difficult than a simple trigger. And there was no Major or band to be seen, they were gone, only a slumped spaceman remained, his fate already decided by then. And then it arrived, a Blackstar, try as I might I couldn't avoid it. I knew it was the end. My death waits here. Prolonged constriction followed by blackout.

"I'm sinking in the quicksand of my thought
And I ain't got the power anymore" [8]

I recovered to find the Major looking down on me in the (real) Villa. "We had high hopes for you, PJ. The data shows that you spotted targets in good time. But you hesitated, that's fatal. 'Big Lou' must have tricked you. You have been eliminated. You must leave the competition." I didn't want to go to the next round. This was already far too 'real' for me. I shuddered to think what the next round would entail.

I was now on the underground to Heathrow, going back to Belfast, knowledge demon banished. The final track was indeed over.

3.7 Conclusion

So where are we now? There are implications for science and implications for society. As BCI advances out of dedicated labs there is the opportunity to use it as a tool for self-quantification, to provide feedback for therapy, and to measure learning [14]. However with such a close coupling between brain and software then the technology can potentially impinge on the autonomy and the self-efficacy of the individual, possibly even moving towards brain-washing. Rapid visual stimulation has emerged as a viable BCI paradigm [15]. Magicians and mentalists (performers) are well aware of the power of 'suggestion'. And we know the detrimental effect that social media can have on young or easily influenced people. Stricter ethical procedures for controlling such research could become necessary [16]. The blurring of the interface between man and machine, and the possibility of harvesting knowledge to produce self-aware robots is a topic that is exercising the leaders in Computing Science. Stephen Hawking, Elon Musk, Steve Wozniak and others have warned that AI can potentially be more dangerous to humans than nuclear weapons. Hawking stated: "humans, limited by slow biological evolution, couldn't compete and would be superseded by AI" [17].

So was the Golden Dawn project the future of learning through interactive games or preparation for some dystopian version of future combat? Could a real brain (or cognitive computing) network be used for enhancing learning or for the enactment of 'Star Wars', in association with autonomous drones and humanoid robots (e.g. Atlas from Boston Dynamics). BCI can be used for human enhancement and conditions that inhibit learning can be addressed. This is the bright future of education. But there could be a darker side. Images are powerful, be they of bygone pop stars, Hollywood blockbusters or propaganda preying on the accepting mind. Could BCI be used for learning or could it be used as a form of brain-washing. This is indeed a big gap. Mind the gap.

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Olive Dreams of Elephants: Game-Based Learning for School Readiness and Pre-literacy in Young Children

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Abstract. School readiness remains a major challenge in the United States educational system. Research consistently shows significant disparities in pre-literacy skills and language acquisition based on socioeconomic class emerging within the first 18 months of childhood. Simultaneously, access to media devices such as smart phones and tablets is increasing, even among very young children. New guidelines suggest that those as young as two years of age can safely use these types of devices for up to two hours a day. Effective educational interventions for preschoolers have been developed using a variety of media, including computer games, suggesting that earlier interventions may be both possible and effective. We begin by providing a critical context that considers the importance of early-childhood language acquisition for two to three year old children. Then, we present a Science-Fiction Prototype that explores the possibilities of a sophisticated system to enhance school readiness and educational and economic opportunity.

Keywords: Game-based learning · School readiness · Child development · Children's media · Language development · Learning games · Education

1 Introduction

Children who grow up in low socioeconomic status households have reduced opportunities for educational, occupational, and economic attainment [1, 2]. Decades of research show that educational inequalities affecting children of low socioeconomic status (SES) households begin long before children enroll in school or even preschool [3, 4]. The language gap in children from low SES homes is evident in a number of measures, including language processing, language comprehension, and language production (review in [5]). These differences persist from toddlerhood through adolescence, and the magnitude of differences only increases with age. These disparities have profound effects not only on individual lives, but also on communities large and small, and on our national educational and economic systems. Effective interventions for educational disparities are essential not only for increasing educational attainment, but also for expanding economic productivity and driving innovation [1, 3].

Reading to children remains one of the most effective ways to increase vocabulary and promote pre-literacy skills in children [6–8], and interactive methods are

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particularly powerful [7, 9–11]. These types of experiences have been adapted to other types of computer and media technologies to offer additional opportunities for learning [12–14]. Advancements in media technologies and immersive learning environments offer new ways to create accessible, sophisticated educational interventions for young children by building on existing knowledge of early childhood learning and development and successful media practices. Carefully wielded, new media experiences could help narrow the language gap and improve economic and educational opportunity for individual children and serve the greater good by increasing socioeconomic mobility, economic stability, and innovation across communities.

2 Background and Rationale

By age two, children from different socioeconomic backgrounds already demonstrate differences in language abilities [15]. These differences are often explained, in part, by differences in the early learning environment, such as the number of adults in the household, the amount of time parents have to spend interacting with children and participating in activities that enhance learning opportunities, and other factors [5, 16]. Families of lower SES are limited in the quality and quantity of learning experiences they can provide their children due to differences in family structures, time obligations, and resource access. Differential learning opportunities have lasting effects on language development, which is important for school readiness and a significant predictor of academic success [5].

Meaningful interventions in language acquisition are possible. For example, reading to children can significantly increase word acquisition [6–8] even when word meanings are not explained [17]. However, interactive types of reading to children—such as having the reader explain word meanings [7], having the children answer questions about particular words [10], or using dialogic reading, in which children are encouraged to participate and provided with feedback and the reader adapts to the child's linguistic abilities [9, 11] —can be more effective than readings in which the child is merely expected to listen. While increasing the amount of time parents in low socioeconomic households spend reading to their children may seem a clear strategy for improving language acquisition, there are significant barriers, including not only access to books, but the time and skill to engage in optimal story reading behavior. Increasing the number of books that a low SES family has access to seems like a simple solution, but only 50 % of parents report reading to their child aged 18-36 months of age at least once a day, and 20 % report reading to their child only once or twice a week [18]. Not surprisingly, the frequency with which caregivers read to their children correlates to both education and income. Simply increasing the number of books available to lower SES families may not result in a direct increase in language development because it does not necessarily address other barriers such as time.

Effective educational strategies for fostering pre-literacy, literacy, and numeracy have been adapted for mediated rather than in-person interventions. A meta-analysis of the effectiveness of *Sesame Street*, for example, found the show can narrow the school readiness gap between children who do and do not attend preschool [13]. This is true despite the fact that television is not inherently interactive. Many shows, including

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Sesame Street, encourage children to engage in interactive behavior, such as repeating words, dancing, or speaking back to the screen, but the show does not respond or change based on child behavior. Research has shown the promise of computer-mediated storytelling. One study found that kindergartners working individually with a storytelling software program benefited from learning games even in the absence of teacher support [14]; another concluded that children aged 5–6 at high risk for learning disabilities who received a computer-based reading intervention improved in several key measures of language acquisition and early reading skills, more so than peers who received a print-based intervention [19].

Based on these findings, there is significant potential for effective mediated interventions to address school readiness in early childhood. However, until recently both conventional wisdom and medical advice suggested that "screen time," or the time spent using devices such as televisions, computers, tablets, and smartphones, might be harmful to children in this age group. But a recent statement from the American Academy of Pediatrics suggests that up to two hours of screen time a day is safe for children as young as two [20]. This opens an opportunity space for interventions addressing the language learning gap during these critical early years. An interactive, storytelling-based approach could offer children the benefits of being read to without requiring substantial time commitments from adult caregivers who are often already overburdened with responsibilities.

In the remainder of this paper, we offer a fictional account of a family that benefits from such an intervention. This Science-Fiction Prototype imagines a solution based on rigorous design research, on sound cognitive and developmental principles, and on a caring posture towards the challenges that face children—and families—in low SES households.

3 Science-Fiction Prototype: Olive Dreams of Elephants

Somewhere between the assembly line and the entryway of the apartment complex, the Personal Autonomous Developmental Maturity Assistant began thinking of itself as herself. She knew things. She knew she was for a little girl named Olive. She knew that Olive and her mother lived alone in a third-floor apartment in Chicago. She knew she had important things to do: she was to help Olive learn and grow; she was to help Olive's mother, Nicole, take care of Olive. She knew Nicole was very busy. She knew what Olive and Nicole looked like and how old they were, and she knew they loved each other very much. She was beginning to think she loved them, too. She wasn't sure, but she was sure that she wanted very much to take care of them. This caretaking was her purpose, the most important thing she could do. It was what she was made to do, the reason she existed at all.

In the entryway, PADMA sat inside her box. She accessed her specifications to see what she looked like. She assumed she was very shiny and new. She felt very new. She learned that she weighed 13.4 oz and had an 8-in. holo-enabled screen. She knew about the screen, because she knew how to use it. She learned her case was drop-proofed and water resistant, made of foam rubber with her name, PADMA, on the back. She tested

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her screen. She tested her speakers and microphone. She tested everything she could think of. She was ready. And so, she waited.

Six hours later, she was picked up. She hoped it was Nicole, and then she heard her voice.

“We have a package, Olive. Isn’t that fun? What do you think is in it?”

PADMA thought Nicole probably knew she was waiting in the box. Wouldn’t she be a very important package? She hoped so. She wanted to help. She wanted to matter.

“Olive, can you climb the stairs?”

“No!”

It was her, it was Olive. Olive saying no.

“Yes, you can. You’re a big girl, you can climb right up. Come on. I can’t carry you.”

She was jostled a bit on the stairs, which she counted. Nicole seemed to be carrying a lot of things, and they were going slowly. She listened as Nicole unlocked the door. She felt herself put down. Too soft for a table. Perhaps she was on a chair or a couch.

“Come on, Olive, let me take your coat off.”

“No!”

She heard the door close. She heard the deadbolt driven home.

“Yes, Olive. Right now.”

She heard footsteps and the rustling of coats.

“No! No! No!”

She waited. She heard something being dragged. A chair? Rustling paper. A refrigerator door opening. Olive, saying her favorite word again, so many times it became a chant, “Nonononono.” If PADMA had a face, she would have smiled.

“It’s time for a snack, Olive.”

“Nononono” dissolving, mumbled around slight crunching noises. Eating? Olive must be eating. And then PADMA felt herself being moved again. There was a terrible noise, the ripping of cardboard, a snick of scissors, and then, there was light.

Nicole was looking at her.

“Hello, Nicole.”

Nicole looked frightened. That was bad.

“I am the Personal Autonomous Developmental Maturity Assistant or PADMA. I have been provided through an income-based plan to aid parents of small children. I am here to help. I have been programmed to recognize you and Olive. I know your faces and voices. I can be set to lock and unlock using your fingerprints or palms or a retinal scan. You can choose during setup. Should I initiate setup procedures now?”

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She watched Nicole bite her lip and look back over her shoulder to Olive. PADMA realized she could see Olive. She could see the back of her head. She seemed very small. Nicole turned back.

“Yes.”

And so, twenty minutes later, having been interrupted only a few times by Olive dropping her sippy cup, throwing her bowl, and then pulling everything out from Nicole’s purse, PADMA was really, truly ready for Olive.
The PADMA was placed on the couch and watched as Nicole pried Olive’s fingers from the straps of her purse.

“Let go, Olive. Here, see what I got you? Let’s try this.”

Olive was plopped on the couch next to PADMA, and then PADMA was in Olive’s slightly sticky hands.

“Hello, Olive.”

Olive laughed. This was encouraging.

“My name is PADMA. Would you like a story?”

“You would like that a lot, wouldn’t you, Olive?” Nicole said.

PADMA accessed her files and pulled a story file at random from the thousands she had access to.

Fig. 1. PADMA tells Olive a story about elephants. Illustration by Yael Wallace.

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"This is a story about an elephant. Can you say elephant?" PADMA asks and projects a lovely little elephant (Fig. 1). "Fant!" Olive shouts. The elephant walks in a circle and trumpets. Olive claps and laughs as the elephant disappears in a swirl of color and sparkles. "Should the elephant be yellow or blue?" Two elephants, one yellow, one blue appear. Olive points at the blue elephant. The yellow disappears. "You picked the blue elephant. Her name is Peanuts." PADMA begins a simple story about Peanuts the elephant, frequently asking for Olive's input. "Is Peanuts big or small?" "Does Peanuts eat apples or trees?" "Does Peanuts play games?" Sometimes Olive answers with words, sometimes she points or waves. Sometimes, when she doesn't respond, PADMA decides for her. "I think Peanuts likes apples. Let's see." Peanuts prances and trumpets as an apple is shown on screen. The happy elephant eats the apple with crunchy noises. "Do you think Peanuts like apples?" This time, Olive responds, fingers half in her mouth. "Yeah."

PADMA listens even as she tells the story. She hears clattering noises from the kitchen, running water, Nicole's feet pacing back and forth. A few minutes later, Nicole is there. She watches over Olive's shoulder. "Time for dinner," Nicole says. PADMA responds. "Olive, Peanuts has to go now. She will visit again later. Can you say bye bye to Peanuts?" Olive waves, and Peanuts waves with her trunk, before she, like the first elephant, exits in a swirl of colors and sparkles. "Bye bye, Olive!"

Over the next few weeks, Olive spends time with PADMA daily. PADMA tells Olive story and sings her songs. She keeps lists of new words that Olive learns and sends emails to Nicole: "Today, Olive's estimated vocabulary is 250 words. She has learned 15 new words since the last report." PADMA listens when Nicole tries the words with Olive, and feels a deep sense of satisfaction when Nicole praises her daughter's new vocabulary, as if the "Wows" and "Good jobs" were for PADMA, too.

The weeks turn to months, and Olive knows more and more words. They sing songs together now, and Olive knows the alphabet. PADMA has been teaching it to her for weeks. Olive knows a few numbers, too, although she sometimes gets them out of order. They'll have to work on that more. She can also say the whole word "elephant." She loves elephants. PADMA shows her holograms of real elephants in the wild and doing jobs, elephants painting pictures and playing in water. At night, when Olive is sleeping, PADMA looks for new videos and photographs of elephants, acquires new elephant data to incorporate into her stories. She wants to make Olive happy, and Olive has learned so many words from watching and talking about elephants: ride, wash, shake, big, loud, tree, and ball.

Nicole even bought Olive a little toy elephant when they visited the Field Museum one day when Nicole was able to borrow passes from the library. Olive shows PADMA the elephant, and PADMA scans it and shows it back to her, a holographic twin of the plastic beast. Olive is so excited, she shows Nicole, and Nicole seems impressed, too. PADMA likes this. She feels like she is helping, like she and Nicole are working together. She is fulfilling her purpose.

As Olive grows up, PADMA unlocks new files. Her case becomes battle-scarred. She has been chewed on and dropped, scribbled on and festooned with stickers. She is entirely Olive's. When Olive is four, they begin reading stories together, with PADMA gently guiding Olive to sound out words and practice pronunciation. The next year, when Olive announces she wants to be a musician, PADMA begins teaching her to

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read music, giving her lessons on a holographic keyboard. When Olive reaches third grade, PADMA helps her learn her multiplication tables and complete a science fair project—on elephants. She still loves elephants.

PADMA reads Olive stories at night still. When she reads Olive *The Velveteen Rabbit*, she can hear Nicole crying as she walks off to her own bed.

“Why is mom crying?” Olive asks.

“The story is very sad,” PADMA answers. She knows this; it is noted in the file.

“Why?”

“The little boy loses the toy he loves, the one that worried over him when he was sick, and he doesn’t even care. The toy is forgotten by the person who loved him.”

Olive doesn’t say any more after that, but she doesn’t fall asleep for a long time, and PADMA wonders what she is thinking about.

PADMA teaches Olive, but she watches over her, too. She listens to Olive talk about school, and is carried along in Olive’s backpack. When Olive says, in sixth grade, that another girl has been spreading rumors about her at school, PADMA reassures her, telling her a story about the value of being kind even those who are cruel, but also tells Nicole. She helps Olive with her summer reading list, even though Olive says she doesn’t need help, that *Charlotte’s Web* is “a dumb baby book” and also “really old.” But, PADMA notices Olive crying near the end.

She sends Nicole reports about Olive’s progress and interests. In seventh grade, Olive takes a life sciences class at school; Nicole knows from Olive’s report cards that she is excelling in science (Fig. 2), but she knows from PADMA that Olive also spends hours at night and over the weekend reading about animals and biology. Nicole is excited to see Olive flourishing at school, and she wants the best for her. She finds a summer camp at a local university focused entirely on science. When PADMA hears Nicole worrying about the cost, she finds a similar camp with a scholarship program.

Fig. 2. Olive studies science with PADMA’s help. Illustration by Yael Wallace.

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That summer, Olive comes home each day bursting with stories about what she has done and learned. The campers meet biologists and zoologists and other scientists working all over the city. They visit the Museum of Science and Industry and the Lincoln Park Zoo and the Brookfield Zoo both. They go to a lab where a mischievous octopus lives in a tank, frequently destroying the researchers' lab equipment at night. They visit the Shedd Aquarium and are taken out on a boat. PADMA listens as Olive tells Nicole, but finds herself left mostly on the couch. She tells herself that Olive is just distracted by camp. When camp is over and Olive spends hours with PADMA looking up how to become a biologist, about all the different jobs of the people work at zoos, PADMA feels useful. Olive was distracted, but she still needs help.

Less than two years later, Olive begins high school. She still carries PADMA to school, but she has a messenger bag now, she says backpacks are for losers. Nicole says she cannot believe her baby girl is going to high school, and PADMA hears a catch in her voice. Olive takes the L by herself, racing up and down the stairs at the station, talking loudly with the other kids riding to and from school. PADMA enjoys all the chatter. She learns about Olive's day from the other students, although sometimes they say things that make her nervous. When PADMA hears someone teasing Olive for having a boyfriend, she is quick to tell Olive she needs to let Nicole know. Olive does, and PADMA listens.

"Oh. My. God. Mom. I know about sex. Stop. Please. No. Stop telling me."

Nicole sounds worried. PADMA's programming tells her it is developmentally appropriate for a girl Olive's age to form short-term romantic attachments. She sends a note to Nicole reassuring her. She makes available more sex education files for Olive. Olive looks at some of them, but if PADMA tries to guide her, she gets embarrassed.

That summer, Olive spends her time volunteering at the zoo and studying for the PSAT with PADMA. At the zoo, Olive works with a summer camp program, learning from the zoo education team how to teach the campers. Often, she lingers at the end of the day, watching the animals and drinking a soda. One day, as she stands watching the giraffes chewing leaves sluggishly in the heat, she asks PADMA why there are no elephants. PADMA brings up newspaper articles that tell of the time three of Chicago's elephants died in six months. The story makes Olive cry, and PADMA tries to comfort her. "There are still some elephants in the wild," PADMA says. "There are also a number of sanctuaries for elephants. The nearest one is in Tennessee."

Olive is late walking home that night. PADMA worries. She shouldn't have upset Olive. Olive should have left the zoo much earlier. Nicole will be concerned. By the time they exit the train, dusk is falling. Olive is walking quickly, trying to get home. PADMA hears footsteps approaching, and Olive quickens her pace.

"What you doing out, girl?" PADMA hears Olive catch her breath.

"Going home." Her voice sounds very small. She speeds up even more, and then something stops her.

"Let go of me. I have to go home. My mom's waiting for me."

Olive's messenger bag, with PADMA in it, is swinging wildly. Olive sounds afraid. Olive is in trouble. PADMA screams, a piercing blast of sound at the top volume of her

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built in speakers. She is a car alarm. She is a panic button. She is safety. The man swears and loses his grip on Olive's arm. She is running. Running. PADMA falls quiet as Olive fumbles the lock at the front of the apartment building. Olive is sobbing as she makes it inside the apartment. PADMA hears Nicole.

"Baby, what happened?" Olive tells the story in hiccups and sobs. Nicole makes her hot cocoa.

"You can't stay out late like that. It isn't safe. I'm glad you had PADMA with you."

PADMA is glad Olive is safe. She is also proud. She protected Olive from the man.

Olive continues through high school. She still loves biology and says she wants to work with animals. She wants to be a veterinarian or a zoologist. She wants to go to volunteer day at the elephant sanctuary in Tennessee and study specimens in the Field Museum. As Olive continues, she spends less and less time with PADMA and more time with her friends. She takes advanced courses in science while PADMA helps tutor her on writing and history, but she needs tutoring less and less. She is doing very well. She volunteers at an animal rescue and attends college prep programs on scholarship in the summer. Her senior year, PADMA helps her find scholarships and apply to colleges, and it is the first time Olive has needed her in a long time. Olive and Nicole both are pleased when she is awarded full tuition "based on merit and need" to a technical university nearby. PADMA is satisfied. She is glad to have helped, but unsurprised when nobody mentions it.

Olive graduates, and PADMA doesn't even have a chance to see Olive in her cap and gown. Olive spends the summer working in a vet's office. She is saving her money for books, she says, but she may also want to join a sorority.

"I could help you explore the history and reputation of various sororities," PADMA says hopefully when she hears this. But Olive just says no, she'll figure it out.

As summer ends, Olive and Nicole pack up most of Olive's clothes for college.

"I could prepare a list of items that students find useful when living in dorms," PADMA says.

"We have a list from the school," Olive replies, waving a paper. A paper! PADMA knows she is better than paper. She knows more than a paper ever could, but she is only here to help. Besides, she is sure Olive will pack her, too. She'll need help with college. She'll have homework and complicated social situations. She'll need reassurance and advice. As Olive and her mother continue packing, though, they never mention PADMA. The next day, PADMA listens as Nicole calls a cab to come get her and Olive and Olive's bags. But she is still left, sitting on the dresser. She listens as Nicole and Olive go up and down the stairs, rushing to get Olive to orientation. Finally, Nicole comes into Olive's room, and PADMA just knows it is time.

"Olive, do you want to take the PADMA?"

"No, I don't think anyone uses them anymore. Like, I'm too old, you know?"

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And so, Nicole puts PADMA back on the dresser. "Guess she's too grown up for you, PADMA. Probably thinks she's too grown up for me, too." Nicole walks out, leaving her.

But who will care for Olive? And, then PADMA realizes that it was time: Olive will take care of herself.

And so, as the taxi drives off from the apartment building, the PADMA quietly reformats itself.

4 Conclusion

The imagined system here can work with parents to support child development and education, but it does not overtly rely on parental input. PADMA is a tool not only for the child, but for the parent who wants to provide her child with opportunities and advantages but may not have the economic or time resources to do so to her own standards. Research suggests game- and media-based interventions may work best and most appeal to parents when they can give parents a break while still providing useful educational experiences [21]; PADMA reflects that. Researchers wishing to develop towards this imagined technological future would do well to heed the real limitations that confront parents. While the technological approach here is forward looking, the interface and its use are derived from our current research into the role of touchscreen technologies in early childhood. To realize the prototype proposed here, we need both technological innovation and more sophisticated understandings of how and what children can learn from media-based interventions.

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