Design, Development and Implementation of Wearable Technology in Football Further Education Settings in the United Kingdom

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ABSTRACT

The prevalence of wearable technology in association football (or soccer) has been prominent in top professional teams for over a decade and is employed by coaches and sport science practitioners to quantify and help improve the performance of either the individual player or team. Educational settings have also witnessed an exponential rise in the application of wearable technology in formal learning environments. The increased number of football industry related qualifications offered by Further Education (FE) and Higher Education (HE) establishments has probably been the driver for this expansion. There is, however, a dearth of research on the educational application of wearable technology in FE and HE. There is also some conjecture as to whether the current wearable technology products on the market, are designed for an educational purpose. The aim therefore of this professional doctorate project was to investigate the use of wearable technology in football related further and higher education settings, and to develop a wearable technology product tool that was deemed appropriate for a FE environment.

Thus, the aim of Study 1 (Chapter 4) was to establish the extent, wearable technology was being used in FE and HE environments. Using a mixed-method research design the initial survey established the type of technology and how they were being employed in FE and HE settings. The study identified that Global Positioning System (GPS) vests and Heart rate chest strap are the most prominent wearable technology. Qualitative findings suggested there are pedagogic challenges and barriers to using this kind of technology, a lack of understanding, and poor feedback and communication.

Having established some preliminary findings Study 2 (Chapter 5) explored these barriers and challenges within contextualised settings in more depth. It identified a disconnect between

coaching performance and coaching education, highlighting a lack of knowledge surrounding the uses and capabilities of wearable technology used in football related FE settings. Furthermore, participant responses suggested the current wearable technology products on the market were not fit for educational purposes.

By designing and developing (Study 3) a bespoke wearable technology product (Chapter 6) provided an industry specific solution to the issues presented in Chapter 5. Adopting a unique collaboration between academia and industry, recruiting experts in various fields, thus enabled the design and development of a novel bespoke system, including the hardware and software requirements reported in Chapter 4 and Chapter 5.

Since the purpose of Study 3 was the development of the wearable technology hardware and software, the aim of Study 4 (Chapter 7) was to evaluate the product and system in an applied real-world setting. Findings suggest student engagement increased, and attainment improved. Additionally, it also demonstrated a more accessible and user-friendly platform for use in FE by eliminating technological features captured in Chapter 5. By using a mobile application and cloud-based system that enabled cross pollination to other curriculum areas suggested college staff and coaches were becoming more engaged with wearable technology. Evidence also suggested students displayed attributes of independent learning and demonstrated engagement outside of formal learning environments.

In summary, the research data and product development presented in this thesis suggest the wearable technology system is fit for purpose and can be deployed in FE environments. From a practitioner perspective, this doctoral thesis has also laid the foundations for education, football, and wearable technology communities the impetus to work in collaboration. This doctoral thesis demonstrates that it is possible for academia, business and commercial enterprise to work collectively to elucidate and solve real world industry problems

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List of Abbreviations

Action Research (AR)

Association of Colleges (AOC)

British association of Sport and Exercise Science (BASES)

British Universities Colleges and Sport (BUCS)

Business and Technology Education Council (BTEC)

Chief Operating Officer (CEO)

Computer Aided Design (CAD)

Coronavirus Disease (COVID-19)

Coventry University Enterprises (CUE)

Education and Skills Funding Agency (ESFA)

Electronic Performance Tracking Systems (EPTS)

Elite Player Performance Pathway (EPPP)

European Data Protection Directive (EDPD)

Fédération Internationale de Football Association (FIFA)

Football Association (FA)

Further Education (FE)

General Certificate of Secondary Education (GCSE)

General Data Protection Regulation (GDPR).

Global Navigation Satellite System (GNSS)

Global Positioning System (GPS)

Hertz (HZ)

High Speed Running (HSR)

Higher Education (HE)

Higher Education Statistics Agency (HESA

Independent Training Providers (ITP)

Information Technology (IT)

International Match Standards (IMS)

International Rugby Board (IRB)

Internetwork Operating System (IOS)

Joint Information Systems Committee (JISC)

League Football Education (LFE)

Liverpool John Moores University (LJMU).

Micro Controller Unit (MCU)

Micro Electromechanical System (MEMS)

National Strength and Conditioning Association (NSCA)

Office for Standards in Education, Children's Services and Skills (OFSTED)

Physical Education (PE)

Printed Circuit Board (PCB)

Quick Response (QR)

Revolutions Per Second (RPS)

Soccer Coaching Limited (SCL)

Small and Medium Sized Enterprises (SMEs)

Sporting Excellence Professional Apprenticeship (SEP)

Strachan Football Foundation (SFF)

Technical Levels (TL)

Technology Readiness and Acceptance Model (TRAM)

Total Distance (TD)

Union of European Football Associations (UEFA)

United Kingdom (UK)

Universal Serial Bus (USB)

Version (V)

Wireless Fidelity (Wi-Fi)

CHAPTER 1

GENERAL INTRODUCTION

1. General Introduction

The aim of a professional doctorate programme is to make a significant contribution to applied professional practice, by creating new, or building on existing knowledge whilst satisfying the university criteria for doctoral provision. To achieve this, the student's role, is to help foster stronger relationships between both academia and professional practice, so they can provide research informed solutions to real world problems (Jones, 2018; Santos, Veloso and Urze, 2020). It is suggested that a professional doctorate, acts an alternative mode of study to that of a traditional PhD; thus benefiting those individuals who may have adopted initially for a non-academic career, by having more relevance in their chosen field and developing a wider understanding of commerce and society (Kehm, Freeman and Locke, 2018).

With the recent worldwide pandemic of COVID-19, and the emergence of the 4th industrial revolution, science, technology and education, face many new challenges and uncertain futures lie ahead. In an everchanging landscape, it could be argued that academia and industry should continue to collaborate to overcome such challenges and work together in solving real world problems. It is this integrated philosophy, which lies at the heart of this professional doctorate and portfolio of work submitted herein.

This introduction chapter will present my professional background and research context. This chapter will also outline the broader doctoral aims and specific research objectives.

Professional Background

I would describe myself as a mature student who entered academia after 25 years of previously working in diverse applied roles and environments. Including, in 1986, a five-year indentured apprenticeship. Achieving a Royal Horticultural Society Gold medal, a Banksian Medal and two flowers receiving awards of merit created for competition and subsequently released for commerce. This process alone takes seven years from the first cross selection of varieties to the eventual release, one of which being presented to Queen Elizabeth the Queen Mother in 2001. During the 1990s, I became a father to three children along with being the main carer. At this time there was a transition into sport, building my own sports coaching business and providing structured physical education in schools. In addition, I was responsible for the management of sports events for Major League Baseball for seven years, including national programme and Playball World Series event manager. With my ever-growing vocational qualifications in sports and progressing employment, including the Rugby Football Union talent pathways, I recognised the need to underpin my hypothesis with science. By doing this, would support my work with succinct evidenced facts that would further progress my career. Therefore in 2007 I entered the academic world, and after gaining entry level qualifications, enrolled and achieved undergraduate and postgraduate degrees in sport science.

Following graduation of these awards I worked as an applied sport science practitioner within a professional football academy and senior team environments that spanned for over ten years. During this time, I continued to apply my emerging scientific knowledge and skills within my work. In addition, I also worked with wearable technology companies to develop and manage systems for the sports industry. I feel that these experiences have a common theme throughout, in that, they have all been longitudinal journeys and ones that I have successfully completed. Being somewhat of a generalist by not specialising in one sole domain or practice, I do however feel that by thoroughly immersing myself in gaining a broad knowledge of the role in, that I have been able to specialise and excel. One of the key attributes to this is by me transferring skills and knowledge gained throughout my career.

My reasons for undertaking the professional doctorate programme are that it will further underpin my practice by evidencing with more depth, a scientific rationale to my applied work. It will allow me to examine more deeply the accepted conventions that constitute my field of work and provide me with the confidence to help to find solutions to questions raised. I have an aspiration to become an expert in the area of research, specifically in the use of wearable technology in applied education and sporting environments. Previously when having to perform academic related tasks to gain qualifications it has helped motivate me to continue to research the subject area. I believe this qualification has the potential to complement industry experiences captured over many years. By conducting a series of studies, I hope it produce answers to questions and recognise the contingency of human understanding in our complex educational world.

On reflection of my development and career to date viewing as being on a theory to practice continuum, I would gauge it currently more on the practice side. By undertaking, the professional doctorate it will for the next few years give me a more balanced progression in my professional development by providing the motivation and goal of a blended working practice. One that I have taken a great deal of thought about before enrolling, since the Autumn of 2017. I spent time researching and evaluating the professional doctorate, with many meetings with students and lecturers including Professor Barry Drust and Dr Neil Clarke. These helped me to determine if a professional doctorate was suitable for me and what I needed to do to prepare for such an undertaking as this. One of my goals in achieving the professional doctorate will empower me with a greater depth to my knowledge of the subject area, as well as making a novel contribution to applied practice in the real world.

A professional doctorate has therefore become increasingly popular with neophyte researchers such as myself, as a mechanism to better connect both academia and industry using a collaborative approach that better equips graduates intending on working in non-academic settings (Zusman, 2017). In their early years, professional doctorates were viewed by some as being below the level of a PhD (Robinson, 2018). However, this disparity has now been largely eradicated as academia as well as industry report on the benefits of professional doctorate programmes (Shin, Kehm and Jones, 2018). Professional doctorates are fulfilling the void identified for HE to diversify away from the traditional programmes on offer as opportunities in academia are ever shrinking (Hawkes and Yerrabati, 2018). Conversely, opportunities within the wider society are growing, as well as witnessing newly created opportunities (Santos, Veloso and Urze, 2020).

For the last 200 years a doctorate has been mainly the focus of a career and life in academia, some would identify that completion of a PhD is the benchmark to success in academia. This by some has been viewed as being narrow minded as it does not reflect changes in the wider society in the modern world (Halse and Mowbray, 2011). Institutions along with sections of society have recognised the need for this diversification and therefore the professional doctorate has expanded and increased at pace, along with being recognised at least equal to, or in the case of industry specific more relevant to a career outside of academia (Bao, Kehm and Ma, 2018; Jones, 2018; Kehm, Freeman and Locke, 2018).

This has also been reflected in Further Education (FE) that is witnessing an exponential growth in educational courses and routes on offer from an increasing number of providers. Most recently in late 2020 the UK government announced that it was again moving its focus towards developing more vocational skills that better help students into direct skilled employment, higher study or apprenticeships. This in the form of the new Technical levels (T-levels) being introduced by the government, which would be phased in over 2021-22 academic years and would streamline the FE qualifications framework and be an alternative to, but the equivalent of three ‘A’ levels, as funding would be targeted towards this pathway (Gov.uk, 2020). Therefore, a collaboration between academia and industry in the context of this current project is justified, as it better links HE, FE, wearable technology and sport industries. In addition, the ever-increasing diversification of industry, specifically the technology sector has seen an exponential rise in small business or small and medium sized enterprises (SMEs).

These SMEs provide scope for more opportunities than ever before for universities and industry to work more closely together than ever before. However, there are some studies that have reported of dangers with such collaborations as some SMEs may not be suited to doctoral student placements (Bertello et al., 2021). Thus highlighting the importance of having a strong supervisory team to support students throughout their studies (Creaton, 2020). This supervisory team along with the employment of continued reflective practice help guide the professional doctorate journey to a successful completion (Halse and Mowbray, 2011).

There are studies that support selecting a professional doctorate for this type of project (Jones, 2018) describing trends in more take up of professional doctorates, the study by Jones mentioned here identified four factors being;

" (1) Employment options within academe are no longer as abundant or secure as they once were; (2) Employers have become more discerning; they are looking for specific skills and qualifications which are absent from the traditional PhD; (3) Government and society are demanding a research degree that is more relevant to the needs of business and the growth of the economy; and (4) universities are seeing the economic value of increasing student numbers, and creating better alignments with industry".

This summarises and reflects the ethos of this doctoral project, as it does set about to create new knowledge for the workplace, and it better connects a multitude of stakeholders and industries. Furthermore, it also adds to the career advancement of the student in industry of sport and education, that are increasingly expanding on their employment of all manner of wearable technology. These diversifications has seen a great appeal to academia as it helps to better understand the requirements and needs of a wider society outside the confines of academia, bringing in experts in given fields to help students to understand the relevance and importance of components of study (Jones, 2018).

1.1 Professional Aims and Objectives

A core component of the professional doctorate journey is to develop professional skills that can be employed in industry. To help me to identify these skills I completed a self-audit, which is situated in the Self Audit and research plan (appendix 1.). This process helped me to highlight components that required further development and the professional doctorate journey will help me to achieve by fulfilling the following aims and objectives:

Primary Aim:

To forge a stronger bond between academia and business to help evolve wearable technology solutions to identified real world problems in industry and evidenced in the overall project.

Objectives:

1. *Develop entrepreneurial skills – working in business by creating a new business to support the project and product development*
2. *Improve and diversify modes of communication*
3. *Personal and interpersonal relationships*
4. *Task and Time management*

A more detailed outline of these objectives is described in the research plan contained within the Self audit and research plan (appendix 1.).

1.2 Research Background

The use of wearable technology in football (soccer) has been established in top professional teams for over a decade (Aughey and Falloon, 2010). It is used for the purpose of helping to understand, quantify and improve performance of the athlete and or team (Seshadri et al., 2017; Luczak et al., 2019). International football federations such as Fédération Internationale de

Football Association (FIFA) Union of European Football Associations (UEFA) and country governing bodies (e.g. The Football Association) have permitted the use of wearable technology in competitive match play and as such it's use during training environments and in formal competition has become the norm (Buchheit and Simpson, 2017). Thus, in recent years there has been exponential growth in the use of technology (Hennessy and Jeffreys, 2018b) which has resulted in the awarding of large, lucrative contracts of three to five years between sporting bodies and commercial providers (Taylor, 2018). Commercial promotion coupled with improved availability has also witnessed the use of wearable technology cascading down the football pyramid (Hennessy and Jeffreys, 2018a) as well into more recreational markets (Krustrup and Krustrup, 2018).

Arguably, the two most common types of wearable technology are heart rate monitors and Global Positioning Systems (GPS) devices (Akenhead and Nassis, 2016). These are widely used to gather objective data, which following analysis are communicated to key stakeholders to help inform three main performance indicators; internal (Bourdon et al., 2017) and external load (McNamara et al., 2018) and tactical traits (Wundersitz et al., 2015b; Bradley et al., 2019). Historically, internal load; is where wearable technology was first introduced and is still used today (McCann and Bryson, 2009). Traditionally this was achieved by using heart rate devices in straps that are worn around the chest area (Figure 1). External load is typically captured from GPS-based devices that are worn centrally on the upper back (Figure 1), and incorporates various inertial sensors, for measuring the locomotor and mechanical loading and positional awareness (Portas et al., 2010). Tactical traits are also being derived from these devices, reporting on positional data of players in relation to their position, formation, and playing style (Tierney et al., 2016).

Figure 1. Heart rate strap monitor and GPS type device in situ on athletes body

With increased use, a greater number of football teams now employ sport scientists, medical practitioners and experts in data analytics and software to work with this technology to help inform performance, recovery from injury and recruitment/talent developmental pathways (Carling, 2013). Data collected from wearable technology is used to measure the demands imposed on players participating in both training and match play (Malone et al., 2015). This objective information, enables coaches to manipulate training and supports the development of the physical and tactical characteristic that are required to meet the demands of the game (Malone et al., 2017). As mentioned previously the increase in use of wearable technology, and the evolving complexity and understanding of how it impacts on other aspects of team performance and development, has seen a surge and growth of support staff such as sport scientist now being employed in the football industry (Rago et al., 2019). In addition, evidence also suggests that individuals, players and the wider public, now take more of an interest in their own performance and are using devices like wrist worn ones providing insight on their current and past activity (Violino, 2016; Thompson, 2018).

Example of use in football is the communication of live feed data to coaches and support staff from players wearing technology whilst training and in match play (Malone et al., 2019).

Furthermore, information obtained such as number and type of movements made, speed and position in match play and training is often used to develop and educate players understanding as they transition from youth to adult development phases (Tears, Chesterton and Wijnbergen, 2018). By manipulating training to improve physical characteristics, and to communicate tactical aspects of the game and thus optimising their developmental physical, tactical and educational performance is the modus operandi of wearable technology (Beenham et al., 2017). However, the way in which physical and tactical components interact and combine to influence the performance of players and teams is poorly understood in the elite performance setting and some have questioned the logic of data-driven practice (Bradley and Ade, 2018).

There is also mounting evidence of the use of wearable technology in educational environments, and this is reflected by the increased use of these devices across both FE and HE settings. Further and Higher education (FE and HE) organisations employ the use of wearable technology in a similar way to how it is employed within the football industry (Ravindranathan et al., 2017). For instance, there is evidence of wearable technology been used with student teams (Gentles et al., 2018), and during components of formal study and for the purposes of research (Albion et al., 2015).

In FE "some" students enrol onto a mode of study which includes affiliation to a professional football academy or the offer of participating in representative football, such as those students undertaking a Business and Technology Education Council (BTEC) type sport course. Evidence would suggest these learner providers engage with the technology, whilst interpreting, visualising and communicating the amount and type of data produced differently, that is relevant to their role, use and setting (Lacome, Simpson and Buchheit, 2018). For the HE sector these developments have led to an explosion in the number of sport related courses and specifically the number of sport and exercise science courses (Roberts & Ryrie, 2011), to meet the demand of the industry, that has seen an ever-increasing number of roles emerge as this sector of support staff grows (Drust and Green, 2013; Dellaserra, Gao and Ransdell, 2014). In addition, the number of providers that offer a blended learning and participation experience has also expanded (British Universities Colleges and Sport (BUCS), 2017). They appear to use data in a similar way to elite teams in providing feedback to players, however this is anecdotal and requires further empirical examination. In contrast to the established use in professional teams (Whitehead et al., 2018), there are no standardised methods or protocols and a general lack of information and conceptual frameworks around their application in educational domains. There is also little known as to how the data generated is used, if at all, in an educational context, as this may make the processes of use different and the effectiveness it has in practice. Furthermore, of the estimated up to 15,000 sport and exercise science graduates each year in the United Kingdom, few are equipped with the skills and knowledge required to work in applied positions, mainly due to a lack of engagement from education with technology and perhaps contributes to as much as 77% of HE sport graduates not being employed in sport related occupations (Sleap and Reed, 2006; Crook and Gu, 2019), this however still requires further empirical examination.

The increasing use of wearable technology by players and the expansion of support staff using continues to grow at pace (Drust and Green, 2013). However, despite the growth in the use of wearable technology, currently there is an absence of a credible conceptual framework for how wearable technology is used in both performance football and in educational settings. Furthermore, despite a number of wearable technology devices on the market (i.e. Catapult, Statsports, Polar, Titan, Playermaker, GPEXE, GPSports, SPT), they may not be relevant for the educational sector. For example, Catapult and Statsports systems widely used in the elite environment have over 250 various metrics and parameters thus creating over 1,000 data points every second (Seshadri et al., 2017), include many proprietary metrics or parameters that differ from each other. Therefore, needing employing full time staff to translate and communicate to various stakeholders in the elite environment. This has more recently witnessed mounting confusion and questioning of these various systems (Rago et al., 2019) and the information they are providing (Collins, Carson and Cruickshank, 2015; Malone et al., 2017). However, in an educational context there needs to be a better understanding of what these "black box" systems are providing, what the data actually means and how it can be used effectively (Bartlett and Drust, 2020) not just in football, but across sport science disciplines (Cushion and Townsend, 2019; Luczak et al., 2019; Nosek et al., 2020) and the potential to go beyond reporting on performance. By interacting across curriculum, thus creating a more cohesive environment by harnessing subjects, and going beyond the confines of the classroom. Our understanding of how this technology is deployed and understood in education environments is even less understood. Therefore, the primary aim of this professional doctorate is to design, develop and implement a wearable technology product in a football specific FE environment. A secondary aim is to establish a working, practitioner-based model for the use of wearable technology in a football specific FE environment.

1.3 Research Aims and Objectives

Primary Aim:

The primary aim of the project is to design and develop a wearable technology product that can be applied in a football specific FE *environment.*

This will be achieved by the following objectives:

1. Identify the extent and type of and approach to the use of technology in football related education programmes in FE *settings*

2. Describe and contrast the use of wearable technology in elite performance and football related FE *settings*

3. Design and develop a wearable technology product and develop strategies to improve effectiveness of use of wearable technology in football related FE *settings.*

4. To propose, construct and disseminate an effective model in the use of wearable technology in football FE *settings*

A more detailed outline of these objectives is described in the research plan contained within the Self audit and research plan (appendix 1.).

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

Despite wearable technology being a relatively recent inclusion in professional football, it is well researched within the broader scientific literature (Rampinini et al., 2015; Akenhead and Nassis, 2016; Scott, Scott and Kelly, 2016; Buchheit and Simpson, 2017; Lacome, Simpson and Buchheit, 2018; Sarmento et al., 2018; Malone et al., 2019; Rago et al., 2019; Vieira et al., 2019). Reviews have evaluated the use of wearable technology in football, however, these have tended to focus more on the performance aspect of use (Aughey and Falloon, 2010; Akenhead et al., 2013; Malone et al., 2015; Akenhead and Nassis, 2016; Hennessy and Jeffreys, 2018b; Whitehead et al., 2018; Rago et al., 2019) and there is scarce information on its use outside of performance, especially in an education setting. Added to this, is that the vast majority of this research has focused at the elite level of the game which represents only a fraction (0.01%) of those that participate in the sport, estimated to be 500 million worldwide, of which 300 million are registered with clubs (Krustrup and Krustrup, 2018). However, with increased availability of wearable technology, there are recent studies that have looked at other sections of the population (Castellano and Casamichana, 2010) including health (Uth et al., 2013; Krustrup and Krustrup, 2018; Randers et al., 2018) and recreational participation (Uth et al., 2013; Randers et al., 2014; Beato, Jamil and Devereux, 2018; Randers et al., 2018; Pantelic et al., 2019).

This current review will first expand on the introduction by providing further background on wearable technology, it will then consider the evolving use of wearable technology in sport and then more specifically in football research and practice. The review will then concentrate more on the use of wearable technology in Further Education (FE) and Higher Education (HE) settings. Finally reviewing the literature around its use for education and the support networks that have grown in the industry of football.

It will examine the category of sport wearable technology, those that are used in sport industry specifically football, more at the elite level where it is well established, the likes of Catapult sports (Canberra, Australia), Polar Electro (Kemple, Finland) and Statsports (Newry, Ireland) being some of the most popular brands (Aughey, 2011; Malone et al., 2017; Whitehead et al., 2018). Additionally, consumer type devices that have become commonplace within society (Aroganam, Manivannan and Harrison, 2019a; Kao, Nawata and Huang, 2019) an example being fitness trackers such as Fitbit (San Francisco USA) that are worn on the wrist (Al-Eidan, Al-Khalifa and Al-Salman, 2018; Kim and Chiu, 2019). Methodological elements of previous research being presented that will underpin and justify the approach of analysis being adopted for this research project.

2.2. Wearable technology overview

Seen as a key component of the fourth industrial revolution (Schwab, 2017; Xing and Marwala, 2017; Akkaya and Kaya, 2019; Atiku and Boateng, 2020) and the internet of things (Metcalf et al., 2016), wearable technology is a category of electronic devices that can be worn as accessories, even embedded in clothing, Powered by microprocessors with the ability to send and receive data via the Internet (Al-Eidan, Al-Khalifa and Al-Salman, 2018).

From being unheard of 50 or 60 years ago, other that is, than those in science fiction novels (Starner, 2002), secret military projects (Roller and Slane, 1998; Winterhalter et al., 2004), or in imaginative gadgets in James Bond movies (Gresh and Weinberg, 2006), being brought to life in the 1960s, with a device hidden within the sole of a shoe containing a small computer used to track the timing of a roulette wheel in the casinos of Las Vegas (Thorp, 1998), to now being ubiquitous within society (McCann and Bryson, 2009; Gilmore, 2016). These hands free devices have grown exponentially over the last 10- 20 years that have many practical uses and found in all aspects of our everyday life (Duking et al., 2018). With some now developed that can be applied directly to the skin, termed E-skin (Miao et al., 2019), which until recently would of only have been found in those science fiction novels and James Bond type movies (Guler, Gannon and Sicchio, 2016; McCrisken and Moran, 2018).

Perhaps the one item of wearable technology that everyone can relate to is probably the mobile or smart phone as is now known, a device that is now so popular it is present everywhere (Parasuraman et al., 2017), which saw it rise from 170 million users in 2010 to over 1 billion users by 2015 (Song, 2010; Kim, Briley and Ocepek, 2015) and latest estimates put this figure at over 3.5 billion globally by the end of 2020 (Statistica, 2019). The rapid rise in popularity of this and other related evolving wearable technology, has placed wearable technology at the forefront of use in physical activity (Brickwood et al., 2019a) and in recent years (2017-2020) repeatedly being the top fitness trend worldwide (Thompson, 2018; Mencarini et al., 2019). With this set to continue as accessibility, type, availability, and our unending thirst for information increases (Alam and Ben Hamida, 2016; de Zambotti et al., 2016).

2.3. Wearable technology in sport

Sporting success is inspirational and we as humans all strive to be associated with it, either through participation (Frick and Wicker, 2016), having products connected to (Stride et al., 2015), or both. Commercial companies have long been adapting and providing all manner of sports related goods for sale, using sport to advertise and promote their products further (Fransen, van Rompay and Muntinga, 2013). The likes of, Timex (Connecticut USA), Tissot (Biel Switzerland) and Longines (Saint-Imier Switzerland), brands synonymous with accurate timing in Olympic and other sporting events, have long used this approach illustrating the use of their technology in sporting events in advertising campaigns, to promote the sale of products such as their consumer based wrist watch (Fransen, van Rompay and Muntinga, 2013; Donze, 2020). Sport like other industries adopted the use of wearable technology, athletes wearing in training and competition, heart rate monitors, with brands such as Polar Electro (Kemple, Finland) promoting to the potential consumer watching (Do, Ko and Woodside, 2015), even with football team kits players wear, that attract multimillion pound sponsorship deals (Thomas, 2015), as well as consumers being able to purchase replica kits on the high street (Stride et al., 2015).

In early use, in sport, a wearable heart rate monitor was launched in 1982 (McCann and Bryson, 2009) and grew in popularity as a means of being able to perform physiological testing and monitoring athletes outside of a laboratory setting as was the norm (Laukkanen and Virtanen, 1998; Larsson and Henriksson-Larsen, 2001). Later other types of wearable technology were introduced to aid in quantifying movement and monitoring the body response to that movement (Schutz and Chambaz, 1997; Lee et al., 2016).

The vast majority of devices used in sport were originally developed primarily to allow for more sport specific testing and continuous monitoring in a setting that the athlete would usually train or perform in, thus allowing for performance to be evaluated in the environment athletes were competing in and outside of a laboratory setting (Schutz and Herren, 2000; Dellal et al., 2008). An example being running performance, previously performed on a treadmill, but could now be performed outdoors on a running track or other surface relating to the sport involved (Larsson, 2003; Alam and Ben Hamida, 2016), allowing for sport specific testing and evaluation of performance (Larsson, 2003). Thus, helping practitioners and athletes to gain a better understanding around and ultimately improve performance in sport (DeMartini et al., 2011; Li et al., 2016; Orange et al., 2019).

Sport has a long history surrounding ethics and privacy, that it has thankfully, continually addressed (Schneider, 2004; Testoni et al., 2013; Simon, 2018). Most notably around cheating (Leaman, 2001) and the use of banned substances such as drugs (Brown, 1980; Orchard et al.,

2006) to gain an unfair advantage. Athletes are continually seeking ways to improve their sporting performance, and some have gone to taking substances to aid this, knowingly or unknowingly that are banned from use in their sport. Whilst taking these substances may improve performance there are many risks to health, there is a fine line between a legal and illegal substance and this varies across sports (Orchard et al., 2006). Sport governing bodies are continually updating anti-doping policies and testing to ensure banned substances are not used by athletes that could give them an unfair advantage over those athletes that are competing clean of any banned substances, this also has the added benefit as it helps to protect the athletes from the many harmful substances to their health and wellbeing (Qvarfordt et al., 2019).

As aforementioned, wearable technology is advancing and there is now technology that can be applied direct to the skin (Miao et al., 2019) and ingested (Berglund, Valentinuzzi and Johnson, 2018). This is nothing new, as electronics inside the human body have been around since the 1950s with pacemakers and other medical devices to aid in patient health, as well as the many worn outside the body, an example being hearing aids (Azariadi et al., 2016). As this current review has identified the potential for wearable technology to present potential issues relating to an athlete's health and wellbeing would warrant further investigation.

Since the introduction of wearable technology into sport there has seen the emergence of more diverse, ethical and privacy issues than before, specifically around the data being produced, how and when it is obtained, the security of information gathered and what it is used for (Page, 2015; Thierer, 2015; Wang and Destech Publicat, 2015). This continues to be part of much wider global issues surrounding data protection and an individual's privacy, brought about by advances in technology in recent years. In response, the European Parliament updated the European Data Protection Directive (EDPD) that had been in place since 1995, publishing in 2016 the General Data Protection Regulation (GDPR). The two of these becoming Europe's new framework for data protection laws and since May 2018 became an enforceable regulation (Voigt and Von dem Bussche, 2017).

Prior to the implementation of GDPR, there were studies that reported on views of loss of privacy from using wearable technology and these ranged from an acceptance of loss of privacy (Page, 2015), to those that view it as an unwanted intrusion (Kotsios, 2015). That said, when conducting this current review of the literature, since GDPR was implemented, it appears that studies have looked in more depth than before, specifically in relation to the implications of wearable technology in sport (Black, Setterfield and Warren, 2017; Socolow, 2017; Arrison, 2019; Peart, Balsalobre-Fernandez and Shaw, 2019), football (Buchheit and Dupont, 2018b; Li et al., 2018; Didulica, 2019), freedom of information (Reijneveld, 2017) and the web of legalities surrounding privacy and security (D'Mello et al., 2018; Wong, 2019).

With recent high profile cases being reported on fines imposed for breaches to the legislation to large companies examples being British Airways (BA) £183 Million GBP and Marriot International £99 Million GBP (Franklin, 2019) illustrates the penalties for breaches. Within the literature there is direct relation to implications of security of data in sport (Peart, Balsalobre-Fernandez and Shaw, 2019) and specifically football (Buchheit and Dupont, 2018a), the urgent need for better regulation (Theisen et al., 2019), transparency (Ausloos, 2019) and more compliant to the individuals rights and control of their data (Barati, Petri and Rana, 2019; Tian, 2020). It is clear from the literature that GDPR in this area is complex and very much evolving (Black, Setterfield and Warren, 2017), it should therefore be included and examined within the context of wearable technology in sport.

Two distinct types or sectors have emerged from the category of sport wearable technology, with these being elite sports and consumer sports. The latter including the likes of the "weekend warrior", a person that usually performs regular physical activity on one or two occasions per week. This normally being at the weekend when traditionally a period of down time from the normal working week allowing time for other pursuits (O'Donovan, Sarmiento and Hamer, 2018; Xiao et al., 2018), example of football being one such activity (Khir et al., 2017) these will both be described and how they impact on sport.

2.3.1. Elite sports

Elite sports, use wearable technology different to consumer types and therefore the development of is also different (Anzaldo and Ieee, 2015; JungHwanCho and 이미숙, 2017; Aroganam, Manivannan and Harrison, 2019b). The main purpose of wearable technology in elite sports is to help understand, quantify and improve performance of the athlete and or team (Seshadri et al., 2017; Luczak et al., 2019), by monitoring the internal and external workload in training (Bourdon et al., 2017; McNamara et al., 2018; Weston, 2018) and match play (Lazarus et al., 2017), providing tactical insights (Wundersitz et al., 2015b; Bradley and Ade, 2018) and injury prevention (Hartwig et al., 2019) or return to play after an injury (Blanch and Gabbett, 2019). Scientific testing and rigour are the norm in developing these types of wearable technology in virtually every sport. Across a wide range of sports (Seshadri et al., 2017), examples can be found across a range of sports, examples including, Baseball (Lapinski et al., 2019), Rugby Union and Rugby League (Hulin et al., 2015; Chambers et al., 2019), cricket (McNamara et al., 2018), and football (Akenhead and Nassis, 2016).

Research in wearable technology use in sport has witnessed an accelerated upward expansion over the last 10 years (Seshadri et al., 2017). More recently, with advances in technology (Miao et al., 2019), our improved understanding (Luczak et al., 2019) and increased availability (Mencarini et al., 2019), the latter has seen these reduce in cost and can now be purchased at a fraction of the cost of early devices that were used primarily in research that would have been over $500.00 USD each (Schutz and Chambaz, 1997), contribute further to indicate that this is an area that will continue to grow and expand.

In this current review recent studies have begun to question and contradict findings from early research, a good example being in Global Positioning System (GPS) type technology. Recently in a study into the use of GPS in football by Malone and colleagues (2019), reported that research had grown from 3 to 136 articles produced per year between 2001 and 2018 (Malone et al., 2019). This current review conducted a similar search as Malone and colleagues reported in 2019, resulted in 153 articles identified in the year 2019, further supporting that this trend is set to continue. Expanding to wearable technology in sport Seshadri and colleagues (2017) performed a longitudinal search of published literature in Pubmed from 1990 to 2016 on wearable technology used in sport, with the literature being published showing it rose from zero per year and still under 50 per year before 2010, seeing a year on year rise, to a sudden upsurge to over 300 articles being published in 2015 (Seshadri et al., 2017). These, all contributing to reasons for choosing this as an area of focus, including that it is integral to the current project and is the most common and fastest growing of all wearable technology used in field based sport such as football (Rago et al., 2019), over the last 10 years (Portas et al., 2010).

The study by Portas and colleagues (2010) was one of the first conducted using GPS technology in field conditions with the sport of football. GPS technology has evolved markedly over the last 20 years in being able to record with some accuracy, on the three dimensional position and velocity of an moving object outdoors (Schutz and Chambaz, 1997; Schutz and Herren, 2000), increases in number of satellites orbiting the earth and sampling frequency being two of the main advances. Sampling frequency is the number of times per second that the GPS device communicates with a satellite to establish the GPS device location. Early devices were recorded at 1hertz (Hz) (Coutts and Duffield, 2010) to 5Hz (Portas et al., 2010; Neville et al., 2011) and these have increased as the technology advances, with studies in team sports recording at over 18Hz (Hoppe et al., 2018). However, most commonly in field sport of football 10Hz are used (Rampinini et al., 2015; Malone et al., 2019), there are studies that question the accuracy of 10Hz calibrated devices at high running speed when compared to timing gates (Yanci et al., 2017) and video analysis (Beato et al., 2016). There are devices that record at higher sampling frequency but found that with increased accuracy then there is less reliability in the data, it would appear there is a trade-off between accuracy and reliability that needs to be considered (Portas et al., 2010).

To combat reliability issues companies create algorithms to help filter and smooth data that contains noise and other unknown inaccuracies and populate with a more optimal estimation therefor appearing to be more accurate, these estimation, are commonly derived from various forms of Kalman filters a minimum- variance estimation for dynamic systems (Madjarov and Mihaylova, 1996). Originally developed for use in linear tracking in the 1960s (Kailath, 1981), these have now advanced, developing algorithms that include extended and unscented Kalman filter for nonlinear problems, resulting in statistical characteristics that are closer to a true value (Li et al., 2015). Furthermore, recently to add to the nonlinear, there has been the development of a more accurate filter named, Adaptive Extended Kalman filter (Hashlamon, 2020). Sport now has the benefit of a further advancement in this area, with study by Zihajehzadeh and colleagues (2015) using an algorithm that included a cascaded Kalman filter found this was far better for tracking human movement (Zihajehzadeh et al., 2015). Although this study involved sports of Skiing and snowboarding, these have many similarities to the sport of football, they involve high speed, whole body, and multidirectional movement (Buchheit et al., 2015).

The development of the technology to provide, higher sampling frequency and improved algorithms, allows for more accurately measured multidirectional movements at fast speeds.

With the vast majority of sporting movements specifically those that occur at key moments in competition, then there is value in being able to monitor increased number of moments that impact on overall performance without interference from external noise. In reviewing the literature on sampling frequency in elite sport there is some controversy on the ideal sampling frequency in field based team sports, specifically football in studies and reviews of the literature (Barbero-Alvarez et al., 2010; Buchheit et al., 2014a; Dellaserra, Gao and Ransdell, 2014; Rawstorn et al., 2014; Vickery et al., 2014; Mallo et al., 2015; Beato et al., 2016; Scott, Scott and Kelly, 2016; Malone et al., 2017; Munoz-Lopez et al., 2017; Castillo et al., 2018; Linke, Link and Lames, 2018; Nicolella et al., 2018; Malone et al., 2019; Rico-González et al., 2019; Willmott et al., 2019).

The sport of football is one reportedly that benefits from a higher sampling frequency, as it is a game of high intermittent movements, therefore a higher sampling frequency can identify rapid changes of speed and direction that are common in football. However, it is complicated, given that football is not cyclic nor predictable in nature, therefore it is necessary to utilize other micro-technologies incorporated within the GPS devices. For example a tri-axial accelerometer, perhaps the third most significant advancement in the technology (Wagner, 2018), as it can provide an even higher sampling frequency (100Hz). Thus, able to better identify these finite movements and movement patterns that present in football than GPS alone (Barron et al., 2014; Kelly et al., 2015; Nedergaard, Robinson and Vanrenterghem, 2015; Fessi et al., 2018; Nicolella et al., 2018; Macadam et al., 2019; Zago et al., 2019). This view is supported further in specific studies investigating accuracy in motion analysis and quality of movement in high speed running (Alexander et al., 2016) explosive sporting movements of weightlifting (Flores et al., 2016), netball (Cormack et al., 2014), and rugby (Howe et al., 2017). In conclusion, GPS devices that incorporate other technology such as accelerometers and combine the two, are more accurate and more able to record these high speed multidirectional movements that occur frequently in football than GPS alone (Barrett, 2017; Malone et al., 2019).

Having information that is more precise of all movement in terms of locomotion in each directional plane, enables practitioners and participants to better understand the mechanical response to specific activities in football, with implications for both injury and performance. With the ability to integrate heart rate monitoring with GPS devices (Akenhead and Nassis, 2016; Alexe, 2019) is allowing practitioners to collect data to determine the relationship between external and internal load from activity and perform more in depth analysis than existed previously (Bourdon et al., 2017; Akubat et al., 2018; Bota et al., 2019; Rago et al., 2019).

A common theme that permeates through the literature is the differing opinions around the metrics or parameters being used and what information should be communicated to coaches to help inform training schedules (Malone et al., 2019). Whilst there are common metrics used when performing sport such as total distance covered, time spent performing activity, various speeds during and maximum speed reached, accelerations, decelerations and position on field of play. Companies supplying wearable technology to the football industry include many proprietary metrics or parameters that differ from each other, examples from three of the most popular used in football being (PlayerLoad ™) Catapult sports, (High Metabolic Load Distance) Statsports, (Training Load Pro™) Polar Electro, as well as there being many others (Malone et al., 2019; Rago et al., 2019). These parameters are not hardware but created algorithms built within the manufacturers or companies accompanying software application that interprets the data produced from the wearable technology being supplied. A good example of the amount of parameters that companies supply is Catapult, these are capable of measuring over 262 parameters thus creating over 1,000 data points every second (Seshadri et al., 2017).

If we take football as an example, there are 90 minutes of play plus added time for stoppages and 22 players in the field of play for the duration of the match. Then on average if all the players were to wear these devices and have all these parameters recorded that would involve the analysis of approximately over 120,800,000 data points per match and that is not including data from warmups and cool downs pre and post-match, substitutes activity and added time. Add to this that the majority of teams in season playing at least once per week, this can be as many as three matches per week and training anything from two to five days per week, then the numbers become overwhelming. (Ekstrand, Waldén and Hägglund, 2004; Gregson et al., 2010; Dellal et al., 2015; Noon et al., 2015; Carling et al., 2016; Carling et al., 2018; Curtis et al., 2018)

2.3.2 Consumer sport

Traditionally, technology such as this would trickle down from elite sports and scientific research to more general consumers, a top-down approach from the scientific laboratory type settings (Larsson, 2003; Alam and Ben Hamida, 2016; Tedesco et al., 2019). However, with the boom in recent years of consumer based wearable technology (Thompson, 2018) such as Fitbit, Nike fuel band and Jawbone (Huang et al., 2016), whether that be fashion (Honarvar and Latifi, 2017) or function (Al-Eidan, Al-Khalifa and Al-Salman, 2018) has seen this buck the norm and is now seen to be trickling upwards (Thompson, 2018; Kim and Chiu, 2019; Mencarini et al., 2019), a more bottom up approach (Thierer, 2015). Whilst the cost of these devices is ever decreasing, thus allowing far more to access (Lynch et al., 2019), dangers have been highlighted on the validity and reliability in devices that are borne out of consumer driven (Berglund, Duvall and Dunne, 2016) based products (Mencarini et al., 2019; Attig and Franke, 2020). Specifically wearable technology developed and used in elite sports, these products have not undergone the scientific rigour of testing previously performed that takes considerable time and money. This is further compounded as technology that is used in studies to evaluate claims made, by the time they are concluded and published, companies have upgraded to a newer version or are onto the next release of a new product (Evenson, Goto and Furberg, 2015).

Recent reports, have questioned some of the most popular consumer brands on the efficacy and reliability of data capture (Huang et al., 2016; Nelson et al., 2016; Haghayegh et al., 2019; Attig and Franke, 2020), that said, there are studies that report on these consumer type devices for measuring physical activity is reliable (de Zambotti et al., 2016; Al-Eidan, Al-Khalifa and Al-Salman, 2018; Brickwood et al., 2019b; Dobbs et al., 2019). These research studies and reviews show that a lot depends on what they are being used for and conclude, that only in low level physical activity are they accurate and once movement and activity increases that they reduce in their accuracy of measures.

In a recent study Kendall and colleagues (Kendall, Bellovary and Gothe, 2019) conducted a treadmill test in a laboratory on a range of consumer type devices, using a larger number of participants than in previous studies (Burton et al., 2018) and across male and female participants, in which they found that devices were reliable, this was in contradiction to the previous study by Burton and colleagues (2018) that found that devices underestimated treadmill walking (Burton et al., 2018). However, the study by Kendall and colleagues (2019) employed a far greater number of participants (n=50) and assessed five of the most popular brands of devices. Being in line with other studies earlier mentioned that supported device reliability at measuring and reporting on physical activity at low level and linear. Kendall and colleagues (2019) further commented that whilst performing on a treadmill in a laboratory enabled for accurate repeatable testing, that a limitation being that this is not representative of higher intensity and multidirectional activity as representative in most sports, therefore it is important to test these products outside in a more ecologically valid situation.

Reviewing consumer sports wearable technology within the literature has seen this sector continue to grow year on year (Thompson, 2018), as described in the previous section it is one that developments are generally consumer led (Mencarini et al., 2019; Nelson et al., 2019) and the aesthetics, novelty of the technology and visualisation of data, all be it without scientific underpinning, are more the drivers than the specificity, reliability and validity of data (Coutts and Duffield, 2010; Dellaserra, Gao and Ransdell, 2014; de Zambotti et al., 2016; Honarvar and Latifi, 2017; Al-Eidan, Al-Khalifa and Al-Salman, 2018; Aroganam, Manivannan and Harrison, 2019b; Brickwood et al., 2019b; Doulah et al., 2019; Kao, Nawata and Huang, 2019).

Furthermore, when reviewing the literature for consumer sports wearables, a recent review by Kim and Chiu (2019), evaluated this from the consumer perspective using the Technology Readiness and Acceptance Model (TRAM) ((Lin, Shih and Sher, 2007). Although it is a multifaceted framework developed from the Technology Readiness (TR) model (Kim, 2018), it does offer quantified insight into consumer led innovations, developments and use of sports wearable technology, that gives a better understanding of the consumer sports wearable technology sector (Pobiruchin et al., 2017; Mencarini et al., 2019). With over 300 respondents to their survey, Kim and Chiu (2019) proposed the use of these type models, could have many practical implications, specifically for manufacturers and designers to help better satisfy their markets. Based on their findings, this study went further by recommending that companies should also look to better educate users around the technology used and be more transparent with the information produced from their products (Kim and Chiu, 2019).

Therefore, further examination and understanding under differing conditions such as multi directional movement and at varying fast changes in speeds such as those encountered in Sports such as football (Bangsbo, Mohr and Krustrup, 2006; Drust, Atkinson and Reilly, 2007; Akenhead et al., 2013; Randers et al., 2014; Beenham et al., 2017) is warranted, if those devices derived from consumer type products are used in sports that require a different level and type of activity. In addition, the education of use to better understand the technology and what outputs are being produced to enable users to be better informed and therefore more able to reach their own conclusions on what is valid, reliable and relevant to its use.

2.4 Wearable technology in football

The devices used in sport specifically those used in football are markedly different from consumer-based devices. There are two main difference, the first being that they have to conform to the sport rules, regulations and laws set down by the sport governing bodies. The global sport governing body for football or soccer as it is also known by is The International Federation of Association Football (FIFA) and has termed wearable technology under the category of Electronic Performance Tracking Systems (EPTS) ((Dunn, Hart and James, 2018). Under the laws of the game of Association football, the use of wearable technology has been allowed since 2015, during competitive match play (Brud, 2017; Linke, Link and Lames, 2018). Football teams have adopted the use of this and it has developed and expanded over the last 10 years, that now sees it being used in most professional teams around the world (Akenhead and Nassis, 2016; Beenham et al., 2017; Buchheit and Simpson, 2017).

This exponential growth in the use of within the football industry, specifically since 2015, has a key similarity to the consumer sector, that of the rate of growth. As stated in the previous paragraph, before 2015 wearable technology was not permitted in competitive match play and limited to the training ground and research studies. Being now able to establish and quantify movement and performance both in training and match play, meant that teams could potentially use this to gain an advantage, whether that be through improved physical performance or tactical insights on own players or opponents to increase their prospects of winning (Bangsbo, Mohr and Krustrup, 2006; Akenhead et al., 2013; Malone et al., 2015; Thorpe et al., 2016; Tierney et al., 2016; Bradley and Ade, 2018; De Silva et al., 2018; Smpokos, Mourikis and Linardakis, 2018; Whitehead et al., 2018; Reche-Soto et al., 2019).

The second main difference, is the way wearable technology has been developed in this area, unlike the consumer type devices these, in their early days of use, have evolved in a more scientific manner, being borne from scientific research over some years both in the laboratory and in the field (Drust, Atkinson and Reilly, 2007; Barbero-Alvarez et al., 2010; Castagna et al., 2010; Coutts and Duffield, 2010; Dellaserra, Gao and Ransdell, 2014; Scott, Scott and Kelly, 2016; Akubat et al., 2018; Bradley and Ade, 2018).

As mentioned previously the most commonly used wearable technology in football are heart rate monitors and GPS derived devices (Malone et al., 2015; Akenhead and Nassis, 2016; Hennessy and Jeffreys, 2018a; Malone et al., 2019), which contain various motion sensors also termed Inertial Motion Units (IMU) or Micro-Electro-Mechanical Sensors (MEMS) (Camomilla et al., 2018). These devices have helped practitioners to quantify physical outputs and give insight to tactical aspects of the game for over 10 years (Drust, Atkinson and Reilly, 2007; Aughey and Falloon, 2010; Malone et al., 2015; Akenhead and Nassis, 2016; Malone et al., 2019). Unlike the consumer type products that are commonly worn on the wrist, those used in football are worn centrally on the upper body. As illustrated in chapter one (Figure 1), Heart rates monitors are generally fitted centrally on a strap, around the trunk just below the chest this enables the heart rate signal to be monitored. The GPS devices tend to be in situ between the shoulder blades centrally on the upper back, this enables the GPS signal, the clearest line of sight from the body to the sky, needed for satellite communication.

There is within the literature, research that describes other types of wearable technology being employed in football, including in the boot (Porta et al., 2012), shin pad (Van Essche, 2015) and now expanding beyond the players wearing, to be within the ball itself (Kryger, Mitchell and Forrester, 2019; Stone et al., 2019) and as technology advances this looks set to continue. Furthermore, outside of the governing bodies regulations and laws of the game (Didulica, 2019), an increasing number of commercial providers hosting a small sided games, termed leisure leagues (Powerplay London UK), are more relaxed with their rules and regulations over participants wearing of technology (Powerplay, 2018). Therefore wrist type devices such as Fitbit and Apple watch can be used to record activity being performed by participants, even participants using a mobile phone with an installed application to obtain data on their performance (Tierney and Clarke, 2019). As previously described within this review, caution should be taken when using different types and levels of technology, even when using in the same sport such as football.

Within the sport of football there are many levels of performer, from playing at a leisure league as detailed above, for general health and wellbeing (Krustrup and Krustrup, 2018) all the way to the top elite (Frick and Wicker, 2016), Globally of the 300 million registered players, 65,000 are registered professionals, with the vast majority could be classified as the elite. However, there is much debate and opinion as to what level separates elite, sub elite, professional in football, therefore for this review professional players have been grouped as one category that includes elite level players. Even if all these are categorised as elite this still only represents 0.02% of the total registered players and only 0.01% of the estimated 500 million global participants (Krustrup and Krustrup, 2018). The Football Association of England (The FA) reported in 2015 that over 11 million people participate regularly in football in England, (Patel et al., 2019) and the Professional Footballers Association has 4,000 registered members with an estimated 3,000 playing being only 0.02% in line with global Figures.

From early devices, specifically GPS derived ones there has been much research conducted. In a recent review by Rago and colleagues (2019) that investigated methods to collect training load (Rago et al., 2019) using GPS type devices reported that collection and interpretation of data varied widely in professional football. This being further compounded with confusion surrounding which metrics to use given the volume offered by commercial companies providing the technology (Malone et al., 2019). In addition, the technology is moving at such a fast rate that earlier research using less sensitive equipment and with some still using, then the reliability and validity is questionable (Scott, Scott and Kelly, 2016).

The use in the field has become increasingly popular (Aughey, 2011) and led to coaches and now, an ever increasing number of sport scientists (Drust and Green, 2013; Akenhead and Nassis, 2016; Lacome, Simpson and Buchheit, 2018; Tears, Chesterton and Wijnbergen, 2018; Malone et al., 2019; Rago et al., 2019) employed, to create periodised training programmes to optimise performance (Alexandre et al., 2012; Drust and Green, 2013; Gaudino et al., 2013; Morgans et al., 2014; Anderson et al., 2016; Beenham et al., 2017; Djaoui et al., 2017; Palucci Vieira et al., 2019) and reduce the likelihood of injury (Gabbett et al., 2014; Buchheit and Simpson, 2017; Rossi et al., 2017; Rago et al., 2019).

The rapid rise and increasing reliance on wearable technology, has seen companies using aggressive marketing techniques and making all sorts of claims (Halson, Peake and Sullivan, 2016) on what their products can do. It is apparent from the literature that science is finding it increasingly difficult to keep up with the speed of these claims in evaluating them. Frustratingly, the majority of these products have locked software systems, closed and somewhat secretive algorithms and an vast array of metrics or parameters (Halson, Peake and Sullivan, 2016) that only adds to the confusion (Malone et al., 2017). Added to this is the speed that products are being introduced to the industry, technology is growing faster than theoretical frameworks that could provide evidence on the effectiveness of use can be produced (Gunawardena et al., 2009) and that there needs to be a clearer alignment between coach and learner education with the advancing technology. This is further supported and described in a recent review of literature of technology enhanced learning in coaching (Cushion and Townsend, 2019). Therefore to discuss coaches is important given the roles that coaches play and the impact they have on their players development and performance (Hay et al., 2012).

Historically coaches would dictate training and it would be their responsibility to increase performance and key performance indicators would be determined from their viewpoint (Cushion, Armour and Jones, 2003; Abraham and Collins, 2011; Weston, 2018). With the increased use of wearable technology, an unprecedented insight is now being objectively obtained (Rago et al., 2019; Reche-Soto et al., 2019) and being integrated to other technology being used such as video camera (Buchheit et al., 2014b). Away from traditional direct coach only observations that have been proven to be less effective to improving performance as coaches are unable to recall as accurately on events (Carling, Williams and Reilly, 2007; Laird and Waters, 2008; Williams et al., 2012) than when using video footage to accurately recall events, being a good example of where technology has had a positive impact to coaching and performance. In contrast the traditional approach that hinder performance (Carling, Williams and Reilly, 2007) specifically in a developmental context (Ward and Williams, 2003; Wright, Atkins and Jones, 2012).

It now means that more than ever before, that players every movement and response to those movements being quantified with the data recorded from the wearable technology. Alongside this, there has witnessed an expansion of roles within football clubs (Hennessy and Jeffreys, 2018b), no more so than those around performance with whole departments being created and continually expanding (Cruickshank, Collins and Minten, 2013; Drust and Green, 2013;

Bullough and Jordan, 2017; Ryan et al., 2018; Tears, Chesterton and Wijnbergen, 2018; Drust, 2019). A recent review of roles in elite sport described this further (Buchheit and Carolan, 2019) that sees these, diluting the singular dictatorship style environment that previously existed, with more professionals as well as more technology inputting on all aspects of performance and athlete management. This does not come without dangers as reported in the literature that having too many contributing could just confuse matters “too many cooks” or “too many chiefs” being typically anecdotes. Thus, further support, that the need for all stakeholders involved to better understand the use of wearable technology in football (Halson, Peake and Sullivan, 2016; Cushion and Townsend, 2019).

Within the literature (aforementioned) there are many studies that illustrate these uses and benefits in performance. Whilst in support of technology, it is apparent that differences exist and lack of uniformity across the football industry on What is the optimal wearable technology to use? how to use it? What measures taken? and where to take them? Also how and when they should be communicated and acted upon (Drust and Green, 2013; Buchheit et al., 2014a; Buchheit et al., 2015; Paul, Bradley and Nassis, 2015; Barrett, 2017; Buchheit and Simpson, 2017; Bradley and Ade, 2018; Jones and Denison, 2018; Carling et al., 2019; Jones, 2019b; Luczak et al., 2019; Malone et al., 2019; Rago et al., 2019).

This is further supported in studies in coaching, coach education, teaching and learning (Stoszkowski and Collins, 2014; Weston, 2018; Kohe and Purdy, 2019). In their recent review of a total of 64 articles, Cushion and Townsend (2019) highlighted that further research in the area of technology enhance learning in coaching is “critically underexplored” and the need for scientific underpinned evidence based research into use of technology and its impacts on coach education and learning in sport is urgently needed (Cushion and Townsend, 2019).

Studies have reported on methods being used, rather than improving performance of players, with its ever growing reliance on and being driven by the data produced, adding to confusion and misinformation (Malone et al., 2019; Rago et al., 2019), is producing autonomous players, or as termed in one study "docile footballing bodies" (Jones and Denison, 2018). This was followed up with a more recent study in an elite football academy setting that confirmed this (Jones, 2019b) and went further, in adding that the data was being viewed as insignificant by these developing players (Jones, 2019b) and this supported with non-buy-in from coaches (Akenhead and Nassis, 2016; Lacome, Simpson and Buchheit, 2018).

2.5. General use in education

Technology, specifically wearable technology, has in recent years started to be introduced into formal education, this has not come without much, controversy, scepticism and even resistance around its use (Crook and Gu, 2019). It appears within the literature there are a number of factors contributing to this; consumer led heightened level of expectations (Ertmer et al., 2012), commercial companies unsubstantiated inflated marketing claims (Anzaldo and Ieee, 2015; Halson, Peake and Sullivan, 2016; Casselman, Onopa and Khansa, 2017), privacy issues (Saa, Moscoso-Zea and Lujan-Mora, 2018), specifically ethical ones surrounding the use of within educational settings (Lee, Drake and Williamson, 2015; de Freitas, Rousell and Jager, 2019; Goodyear, Kerner and Quennerstedt, 2019).

Like all industries, academia has to continually adapt to ever changing market needs (Donze, 2020), education settings have to ensure programme of study is relevant to meet students continued education and is aligned, with fulfilling requirements for successful employment post-graduation (Lynn, 1999; Siddoo et al., 2017; Jung, 2019). In recent years, it has seen technology become established in the sector (Castro, 2019). From early forecasts (Farrar, 2003) that technology would extend beyond the scope of teaching in a lecture theatre and that this could lead to an anywhere, anytime, learning experience (Schaffhauser, 2014). This introduction to the use of technology has witnessed a dramatic change in education, from the age-old tradition of lecture theatre delivery and classroom-based learning (Farrar, 2003; Majeed, Ali and Ieee, 2018). To the present, in what has become known as a blended learning environment (Turney et al., 2009; Serrano et al., 2019), being widely adopted in both HE (Graham, Woodfield and Harrison, 2013; Bokolo et al., 2019) and FE (Haugen, Ask and Bjoerke, 2012).

A good example of how education has changed, is with the use of the mobile phone, (McFarlane, 2019). It has increased in such popularity, that this technological device is now being widely used within education (Artal-Sevil, Bernal-Agustin and Dominguez, 2015). But is not without its dangers, calls were made early this century, for more in-depth research into how technology can improve learning and the contextual factors involved (Alavi and Leidner, 2001), across the HE and FE settings. In response, studies and further reviews of these were conducted (Kim, Grabowski and Song, 2003; Ferdig, 2006; Fleischer, 2012). One study by Kvavik (2005) highlighted, that education was complacent as it had an expectation that students were well versed with skill in use of technology, where in fact, the majority of students required training and the few that had a high level of skill had mixed feeling around its use in a learning environment, this study concluded that technology had great potential in the education setting (Kvavik, 2005).

A later study (Artal-Sevil, Bernal-Agustin and Dominguez, 2015) reported mixed feedback from student use, whilst motivating them to interact with technology and increase learning opportunities, the flip side is that it could cause too many non-educational related distractions (Yunita et al., 2018). This could be argued that it is in fact a learning experience in itself as the students continued interaction with this mode of education enhances self-discipline and ability to disseminate information better (Balliammanda, 2021).

However, even with the dangers highlighted, this continues to expand and not limited to these mobile devices, as education integrates more technology, including that of wearable technology (Babic, Gaspar and Satala, 2018; Havard et al., 2018; Ameen et al., 2019; Peters and Romero, 2019; Strimel et al., 2019), this includes an array of different wearable technology including students own technology such as general consumer wrist based devices (Violino, 2016).

This could be one of the many reasons for such divided opinion, that is causing confusion around wearable technology uses and highlights the need for better education in the differences (Albion et al., 2015; Al-Eidan, Al-Khalifa and Al-Salman, 2018). Students and teachers need to understand all the potential implications that using wearable technology can bring by its inclusion in the educational journey (Bower and Sturman, 2015).

A recent study (Crook and Gu, 2019) looking at the relationship with researchers and limits in educational studies involving technology, highlighted various issues emerging, including that educations engagement with new technology was lacking and in many ways being overlooked by academic researchers in an educational context. Thus, the need for better integration from research to practice is required (Fishman et al., 2004; Albion et al., 2015), further supported in an recent empirical review of the literature that found that without formal structure and teacher buy in is problematic to technology in education (Harper, 2018).

There are other studies that have identified technology becoming more in mainstream use within education (Teixeira, Bates and Mota, 2019), but it is important to recognise that this is dependent on the complex and multitude of factors that determine use and in what context that has presented here within the literature (Alavi and Leidner, 2001; Ertmer et al., 2012; Artal-Sevil, Artacho and Romero, 2015; Artal-Sevil, Bernal-Agustin and Dominguez, 2015; Alhabeeb and Rowley, 2018) and more recent review (Choudhury and Pattnaik, 2020). What is emerging from the literature is that when implementing educational strategies that fully involved technology it was having a positive impact (Niederhauser et al., 2018; Mora et al., 2020). However, highlighted in the study by Niederhauser and colleagues (2018), the threat to education is high, specifically HE of scaling and sustaining programmes due to continuing changing of technology and factors such as social interactions (Crook and Gu, 2019), ethical issues around privacy (Engen, GiÆVer and Mifsud, 2018) and teachers resistance to use (Yoon, Ho and Hedberg, 2004; Sole Blanch, 2020), therefore, we need to better understand its use across the educational landscape (Bower and Sturman, 2015).

2.5.1 Wearable technology in higher education

As technology advances, we witness more and more tasks being performed by machines and technology in established as well as emerging economies (Wesche and Sonderegger, 2019), the need to adapt to these changes is evident. A recent study highlighting this (Jung, 2019), described how not only technological industry, but also HE must have the ability to adapt to this fast-paced ever-changing landscape. The fear being that education does not keep track of these changes in the marketplace, thus creating a gap that would take considerable time and resources to fill these professional roles (Wang et al., 2020).

That said, in a recent review of the literature in this area by Avis (2018) concluded that technology, like all fast-moving industry involves a multitude of factors that are complex and there is no expected employment crisis (Avis, 2018). Furthermore, there is no impending doom of technology taking over (Lynn, 1999; Wesche and Sonderegger, 2019) and is further supported in studies evaluating the labour market (Gallie, 2017). As stated earlier in this review, this is mirrored in sport, specifically football that has seen an exponential rise in the use of wearable technology a good example being newspaper reports of long term (5years) large scale contracts specifically in football of over $1 billion USD (Taylor, 2018), further underpins the evidence that this sector continues to grow and will do for some time.

In response to all these, HE has been seen to adapt, with the inclusion of technology (Haugen, Ask and Bjoerke, 2012; Artal-Sevil, Artacho and Romero, 2015; Abu-Ayyash and Hill, 2019; Crook and Gu, 2019; Granic and Marangunic, 2019; Harju, Koskinen and Pehkonen, 2019), specifically all manner of wearable technology within their curricula and extended activities (Farrar, 2003; Artal-Sevil, Bernal-Agustin and Dominguez, 2015; Bower and Sturman, 2015; Marie-Sainte et al., 2016; Masters et al., 2016; Majeed, Ali and Ieee, 2018; Prieto et al., 2018; Abu-Ayyash and Hill, 2019; Goad et al., 2019; Nelson et al., 2019).

Sport and exercise science degrees have long been established in UK universities, as being the mainstay of academic qualification required to progress into post graduate employment. More recently this has started to change as there are now an increasing number of related courses, examples being performance analysis and coaching. The Higher Education Statistics Agency (HESA) reports that over the last 5 years in England the provision of sport science related undergraduate degree courses has grown from one to over 10 in 2018 (HESA, 2019) and that this is set to continue to grow. The number of sports coaching courses on offer was reported as being over 245 in 2009 a marked rise from 2001 when only 26 institutions were available for courses on offer (Hall, Cowan and Vickery, 2019). This study by Hall and colleagues (2019) focus was investigating the employability prospects of sports coaching degree graduates and concluded that practice-based learning in the field along with improved modes of communication and developed interpersonal skills were key requirements that increased employability prospects (Hall, Cowan and Vickery, 2019). In addition, the need to increase the number of sports coaches qualified to bolster this workforce being continually highlighted in recent years within the literature (UK.Coaching, 2017; Hall, Cowan and Vickery, 2019).

Many of the scientific research studies conducted at universities including these involving students now include ones that are employing the use of wearable technology. The most popular being heart rate monitors and GPS based devices.

These recent accelerated changes in education are not without dangers, as like with the rise of wearable technology innovation discussed earlier in this review, there needs to be a structured framework and set of standards around type and use and in depth investigations to better evaluate effectiveness within educational uses (Bower and Sturman, 2015; Attallah and Il-Agure, 2019). Additionally that these should include teachers and students (Kinney et al., 2019), an example being, where educational establishments, like general consumers, have purchased equipment not fully understanding the specific uses or potential uses and thus being ineffective (Yoon, Ho and Hedberg, 2004; Bower and Sturman, 2015; Engen, GiÆVer and Mifsud, 2018).

It is evident that wearable technology is becoming integrated and enhancing student experience through an ever-growing blended learning approach, but is not without threats to its continued evolution in uses (Evmenova et al., 2019). HE is changing and as this sector continues to evolve the need to understand what and how wearable technology is involved is needed and perhaps a more agile approach to evaluating its impact is required.

2.5.2. Wearable technology in further education

Further education (FE) is well recognised as the pre cursor to HE and ultimately employment, whether that be direct from FE or post HE graduation (Reay, Crozier and Clayton, 2010; Gartland and Smith, 2018).

Colleges, like Universities, have also embraced this blended learning approach (Braun, 2019) and as such have radically changed in recent years (Burnell, 2017). This has witnessed an overhaul of their core course the Business and Technology Education Council (BTEC) suite of qualifications that has been around for over 30 years (Carter and Bathmaker, 2017; Braun, 2019). There were other factors that contributed to these changes including; reports that technology was introduced too hastily, not fully understood (Alhabeeb and Rowley, 2018) and without in-depth research into its use in science education (Hobley, 2016). With blended learning being adopted in use it needs to be integrated more effectively into the teaching framework (Dear, 2017; Castro, 2019; Choudhury and Pattnaik, 2020), to better equip students with the knowledge, skills and learning experiences that will ensure an effective transition from FE to HE (Peake, 2018), or with the added practical knowledge to access employment (Spence and MacNamara, 2018; Hall, Cowan and Vickery, 2019).

The BTEC sport science suite of qualifications has also undergone these changes, that includes the inclusion of technology and more specifically wearable technology, across its core and optional units that students must complete and pass to gain the relevant qualification (Pearson, 2019b). With these being available from September 2019 and first certifications towards the end of 2020 (Pearson, 2019b). Another addition to this changing landscape is that of a new Technology Level qualification (T-Levels), being a new programme at level 3 introduced to simplify a confusing and everchanging qualifications landscape, along with promoting a technical education for increased employability (Foster and Powell, 2019). Intended by government to better prepare students to advance into level 3 and beyond under this new qualifications framework (Education, 2020) All these being deemed to offering now more specific pathways, an example being coaching, leading into the next phase being an undergraduate degree course as described in the previous section, or direct employment (Foster and Powell, 2019; Avis et al., 2021).

Whilst there is a devoid of literature on wearable technology in HE and FE, the few related studies there are, highlight the potential there is when integrated into the educational process (Bower and Sturman, 2015; Aldous, Sparkes and Brown, 2016; Pascopella, 2016; Engen, GiÆVer and Mifsud, 2018; Attallah and Il-Agure, 2019; Evmenova et al., 2019; Kinney et al., 2019). Further supported with more in depth applied studies (Evmenova et al., 2019) that have concluded that where wearable technology applications are allowed to develop further and refined within specific educational programmes resulted in, both increased teaching and learner engagement and interaction (Evmenova et al., 2019). Furthermore, it has shown to have positive outcomes (Dray and Howells, 2019), including within sports coaching (Turick, Bopp and Swim, 2019). This would warrant further investigation into what benefits there are in these settings and potential barriers to introduction or continued use (Kinney et al., 2019).

2.6. Sport science support in football education

The football industry is well established in society, within the playing department of a club, there is a support network that works behind the scenes with the team to aid in the team performance. Traditionally this would consist of a manager, coach and medical practitioner (Drust, 2019), as our understanding of performance along with advances in technology have increased, this has seen an exponential increase in the support network behind the scenes at clubs (Rago et al., 2019). Sport science is perhaps the largest of these areas that has seen the most growth (Drust and Green, 2013; Akenhead and Nassis, 2016). Including in this area is a range of roles that have become more specialised (Lacome, Simpson and Buchheit, 2018; Read et al., 2018; Tears, Chesterton and Wijnbergen, 2018).

Historically, sport science has been defined as an interdisciplinary area (Williams and Ward, 2017) and the provision of these courses at degree level continue to be well catered for (HESA, 2019). Providing graduates with a foundation of general knowledge on sport science and with an increasing number of institutions now offering more specialist courses (Araya, Bennie and O'Connor, 2015) or added components to courses that expand on the general knowledge gained (Armour and Chambers, 2014). Thus, seen to be helping to fulfil the football industry needs where these roles have been recently created and continue to grow (Akenhead and Nassis, 2016; Buchheit and Carolan, 2019; Drust, 2019). In addition to the aforementioned changes, football is a fast-paced sport and this is mirrored in its environment, unlike other sports such as those on an Olympic cycle, where research and more affordably, longitudinal research can be conducted. Football, specifically the higher up the levels you go, does not afford the luxury of time to conduct and evaluate research (Buchheit and Simpson, 2017). An example being that with the congested fixture schedules that may impact on periodised training models. Or the performance of the team, if they lose and if this happens with some consistency, then there is the ever-revolving door of managers and support staff changing. In view of this, then the better we are able to equip support staff, specifically newly graduated sport scientist to perform at the levels required early in their career or " hit the ground running ", then the better chance they have to gain employment and progress in their given career (Buchheit, 2017).

Not only do they have to use the technology, but they also have to educate coaches, players, parents and other stakeholders on its benefits (Weston, 2018; Luczak et al., 2019; Malone et al., 2019). It is imperative that clear differences in types and use are understood, an example being the coach or parent who may use an consumer based activity tracker for their own exercise and then mirror their activity data with that of the player, making a direct comparison instead of relating their performance to perhaps a more advanced technology being used with players.

There is emerging evidence that technology, specifically wearable technology, is being employed more to determine what is done both in training and match play (Hennessy and Jeffreys, 2018a; Malone et al., 2019; Rago et al., 2019). The advancing technology is now enabling more to not only access their own data immediately, but can also give quantifiable analysis on their own individual performance, thus empowering more players to view an ever growing amount of data on their performance (Halson, Peake and Sullivan, 2016). This could lead to conflict given the information within the literature on the many dangers (Paul, Bradley and Nassis, 2015; Carling et al., 2019; Malone et al., 2019). However, the power coaches traditionally have held and as highlighted here in this review, that some are employing wearable technology to reinforce almost dictatorship philosophies (Jones, 2019a). The study by jones (2019) even though small in size of number involved and in one setting used for the study, it does hold merit to be included in this review, as it was in a professional football club in England and the participants were ones that also were students involved in FE and were using wearable technology. Furthermore, it supports findings from earlier studies that concluded that it led to authoritarian coaching styles (Williams and Manley, 2016; Blackett, Evans and Piggott, 2019) which is not what the technology was intended for. However, the study by Williams and Manley (2016) was in a different sport (rugby) and also only involved a small number of participants, whilst their conclusions pointed to it leading to authoritarian coaching styles and this has been shown to be the case in a more recent study by Blackett and colleagues (2019) in elite football academy setting (Blackett, Evans and Piggott, 2019).

There are others (Collins, Carson and Cruickshank, 2015) that disagree with these and concluded that technology has a positive effect resulting in improved performance behaviours (Cruickshank, Collins and Minten, 2013). Presenting within the literature that much conflict and confusion specifically surrounding wearable technology in the sport of football exists (Akenhead and Nassis, 2016; Wright et al., 2016; Buchheit and Simpson, 2017; Neto, 2017; Hennessy and Jeffreys, 2018b; Lacome, Simpson and Buchheit, 2018; Weston, 2018; Carling et al., 2019; Malone et al., 2019; Murray and Varley, 2019; Rago et al., 2019).

Historically the sport of football has embraced change, and some have been so monumental that they have changed the landscape, one example which occurred in the 1990s is that of the Fitness Trainer being replaced by Chartered Physiotherapists. Here saw a bastion of the sport for over 100 years, the Fitness Trainer who was in almost every football club (Carter, 2010). Traditionally, a common sight is that they could be seen to stand at the side of the pitch with their bucket filled with water and a sponge, sometimes termed “the magic sponge” who when a player went down injured then they would run onto the field of play, douse the players injured area with a water filled sponge, and the player would then jump up and continue to play as if cured by magic (Malcolm, 2011; Malcolm and Safai, 2012), being replaced with a Chartered Physiotherapist (Carter, 2010). A much-needed change and has been proven since these changes, to advance the sport at every level in terms of player care, the formal medicalisation that is now in place was much needed (McEwan and Taylor, 2010; Malcolm, Scott-Bell and Waddington, 2017). Whilst not leading to the demise of a profession in football of coaches, it is imperative that wearable technology use in football be investigated further to determine how wearable technology can be employed effectively in football ensuring it remains agile to the advancements being made in this fast-moving area of technology.

Added to this, is the exponential rise in diverse roles within the industry, rather than moving away from traditional coaching and support staff these are adding to and expanding including the use of more science and technology than ever before (Ryall, 2019). These aforementioned studies reviewed, all had common messages that better understanding, accurate uniformed information and communication were needed, along with careful consideration as to what, how and why being used, will lead to harmony and better working relationship between support staff including coaches and player. Thus, resulting in increased player "buy in" allowing them to perform (Brink et al., 2018; Weston, 2018; Nosek et al., 2020).

As like the demise of the fitness trainer with their bucket and sponge approach, being replaced with a professional body with professional standards in Chartered physiotherapists employed in football clubs and at varying levels (Tears, Chesterton and Wijnbergen, 2018). These follow set procedures and are governed by national governing body minimum standards. The inclusion and expansion of sport science in football has also witnessed this with British Association of Sport and Exercise Scientists (BASES) accreditation and standards governing practice. These are two areas that are increasingly using wearable technology, therefore it makes sense that the technology they are using and how they are using should also be. FIFA has started to address this by publishing minimum standards for EPTS (FIFA, 2019), but needs, along with the industry, to go further, given the issues surrounding privacy, misinterpretation, miscommunication, validity, reliability of data and a now unprecedented availability to access, as described in this current review of the literature, there are potentially far reaching damaging consequences. In contrast, rather than improving performance and reducing the likelihood of injury, that, the opposite is happening including; causing insecurity (Kohe and Purdy, 2019), confusion (Malone et al., 2019), prejudice (Jones, 2019a), underperformance (Collins, Carson and Cruickshank, 2015), risk of injury (Halson, Peake and Sullivan, 2016), stress to the point of almost dehumanising players (Williams, Manley and Millington, 2017), and a total lack of mistrust and alienation between players and support staff (Toner and Jones, 2016; Luczak et al., 2019).

2.7 Summary of the literature review

The need for a better understanding of applied practice in the use of wearable technology within the football industry is apparent. The reliance on an increasing number of commercial suppliers providing their interpretation and communication of the information produced from this equipment has led to questioning of its effectiveness (Bradley and Ade, 2018) in improving performance, monitoring performance and injury prevention (Buchheit and Simpson, 2017; Varley et al., 2017). Furthermore, the pace of advancing technology improvements is adding to the controversy around its use in sport and increases lack of trust and resistance to use from key stakeholders (Weston, 2018; Jones, 2019a; Luczak et al., 2019). In addition, an increasingly number of metrics being offered by companies is causing much confusion surrounding communication of the data in football (Malone et al., 2019; Rago et al., 2019).

There is a dearth of evidence within the limited amount of literature surrounding the use of wearable technology in FE and HE. In part due to its recent inclusion, into educational settings such as these and the technology only recently being developed and made available. Furthermore, our lack of knowledge, understanding and modes of communication employed is also apparent (Bartlett and Drust, 2020). Additionally with the increase of more support roles within football using this technology and with these being filled by ever higher qualified candidates (Buchheit and Carolan, 2019), are starting to question the technology provided and claims they make (Akenhead and Nassis, 2016; Hennessy and Jeffreys, 2018b).

In addition, the recent changes in these education sectors provision most notably, increased use in both FE and HE through the expansion and diversification of teaching and learning. The overhaul of sport qualifications in FE and expansion in HE of more specific football science related courses. The increase in number of post 16 educational providers offering blended learning approaches that includes vocational sports coaching and participation in football at varying levels require further investigation. Hence, it would be appropriate to explore further to determine if it is being used, who is using it, what is being used and how it is being used in football related FE and HE settings.

Finally, the recent COVID-19 pandemic that has brought about unprecedented changes to the world we live in. It has impacted massively in sport and education, so much so that both ceased at one point and this continues to be sporadic as society develops responses to the pandemic in addition to any vaccine. Sport and education are both seeking alternative methods of delivery to enable them to continue in this now fluid environment. Wearable technology is also having to adapt to this new additional phenomenon. Thus, it is imperative that the use of wearable technology in educational settings as described is better understood, therefore, this will be explored in a series of studies.

CHAPTER 3

Methodological Framework

"Look, Think, Act"

3.1 Action Research

In terms of the methodological framework that guided this portfolio of work, it could be best described as Action Research (AR) ((McAteer, 2013). Action research is characterised, not as a single methodology, but as an approach that encompasses a variety of methods (Coghlan, 2011). As such it provides the researcher with a range of 'tools' to better investigate and evaluate the work that needs doing. It also helps the researching practitioner to understand what and how something is being done, and better understand if improvements are needed, what they are and how to improve (McAteer, 2013). In the context of this current portfolio of work it was decided this approach would be more conducive to 'telling it as it is' rather than how the researcher 'thinks it should be'. With this in mind, and the proposed development and design of a unique system deployed in a live setting it was envisaged that this would require changes to meet potential unknown demands. It was further anticipated that the findings from each of the applied studies would complement and inform the next stage, following careful scrutiny of the researcher.

Therefore, the AR approach adopted for doctoral project is described in three sequential stages or the "look", "think", "act" process (Stringer, 1996). This approach has much support in the empirical literature and is suited to this current doctoral project, given its previous application in education setting's (McKenna and Dunstan-Lewis, 2004; Stewart et al., 2010). Moreover, by recruiting research participants from various educational environments, namely students, coaches, and FE lecturers, all contribute to a complex system that is meaningful to all involved especially when participants are actively contributing to the decision making process of the research (Koch et al., 2005). Moreover, when underpinned with the key principles of building and developing relationships, communication and inclusive participation (Stringer and Genat, 2004), Specifically with the adoption of this type of action research approach in educational settings by including teaching staff in the process has wider benefits to all related stakeholders (Morales et al., 2016).

The following chapters contained in this portfolio of work will present how the “Look”, “Think” and “Act” model was applied in a real-world research environment and how this research framework was integrated into a series of applied research studies. For example, the applied research studies one and two are positioned in the “Look” phase and include a series of data collection methods to establish the types and approaches of wearable technology in educational and football specific environments. The “Think” phase (i.e. Study 3) signifies the largest proportion of work included in this portfolio, and illustrates the processes that were involved in the design, development, reliability and validity of a wearable technology product considered appropriate for a formal educational environment. The final “Act” stage (i.e. Study 4) included the deployment and application of the wearable technology product in a FE environment. The next stage of this portfolio will present these applied research studies and attempt to provide evidence of how they meet the doctoral aims and research objectives presented in Chapter one.

CHAPTER 4

Research Study 1 "Look"

Identification of the extent and type of and approach to the use of wearable technology in football related education programmes in FE and HE settings

4.1 Introduction

Association football (i.e. soccer), like many sports has embraced the use of technology (Hulin et al., 2015; McNamara et al., 2018; Lapinski et al., 2019), specifically wearable technology (Seshadri et al., 2017), growing exponentially in recent years to become common place (Buchheit and Simpson, 2017; Hennessy and Jeffreys, 2018b). This growth continues at an accelerated rate across the expanse of the football landscape and is reported to include: recreational, also termed leisure football (Krustrup and Krustrup, 2018), and football related health programmes (Randers et al., 2018). To support this expansion, the football industry is also witnessing an increasing number of support staff roles such as; sport scientist, strength and conditioning coaches, performance analysts, amongst other job opportunities being created within clubs and teams. These range from more traditional roles involving an increase use of technology, to new roles such as data analysts, that use data produced from wearable and other technologies (Hennessy and Jeffreys, 2018b; Jones, Rands and Butterworth, 2020), also highlighting the need for education in the use of wearable technology in football type environments (Drust and Green, 2013; Buchheit and Carolan, 2019; Rago et al., 2019).

From an educational perspective FE (i.e. 16+ Colleges) and HE (i.e. universities) establishments, have also witnessed an increasing demand for wearable technology with their competing teams (Ravindranathan et al., 2017; Gentles et al., 2018), along with some during components of study and research (Albion et al., 2015). As availability and demand increases for the use and application of wearable technology in educational domains, it has become apparent that the practitioners and academics responsible for the use of this technology need to better understand the complexity of wearable technology as part of an increasingly blended learning sport science experience (Harrison et al., 2020). Furthermore, the educational sector is also witnessing an explosion in the number of sports coaching related courses (Roberts and Ryrie, 2014) on offer increasing, reported as being over 245 in 2009 a marked rise from 2001 when only 26 institutions were available for courses on offer (Hall, Cowan and Vickery, 2019). This is further supported in reports highlighting the need to increase the number of sports coaches qualified to bolster this workforce (UK.Coaching, 2017; Hall, Cowan and Vickery, 2019).

Recent changes in FE related courses such as the newly revamped BTEC sports qualifications framework, now include wearable technology within core and optional units (Pearson, 2019a). The FE sector is of particular importance as it acts as a conduit from secondary education and post 16 learning to either direct employment (Spence and MacNamara, 2018), or an entry route to HE such as university (Gartland and Smith, 2018). Within the FE sector, categories range from School 6th Form, Colleges, Charities, to various private training companies, that provide a blended learning experience (Braun, 2019), consisting of a mode of study with applied industry related practice. Many of these establishments now offer an added incentive of participating in representative football, such as students undertaking a BTEC type sport course (Spence and MacNamara, 2018) along with training and playing football that is mirrored in the professional game (Bullough and Jordan, 2017). There is also evidence of FE provision within the professional game in the UK, being part of the previously described EPPP framework (Tears, Chesterton and Wijnbergen, 2018), that provide a formal education of early year potential professional players whilst continuing to progress their careers (Gledhill and Harwood, 2015).

It is not known if or how, FE providers collect and use data and if so is this in a similar way to elite teams use in analysing performance and providing feedback to various stakeholders. Personal observations as well as discussions with colleagues working in the industries, over the last 10 years points to some FE providers are starting to collect and use data, this does require further empirical examination.

In contrast to the established use of wearable technology in professional teams (Whitehead et al., 2018; Malone et al., 2019) there are no standardised methods or protocols and a general lack of information and conceptual frameworks around their application in educational domains. There is also little known as to how the data generated is used, if at all, in an educational context compared to performance domains. Furthermore, of the estimated 15,000 sport and exercise science graduates each year in the United Kingdom (UK), evidence suggests that few have the necessary skills and knowledge required to work in applied positions, mainly due to a lack of engagement from education with technology (Crook and Gu, 2019) and that up to 40% of HE sport science graduates seek employment in other industries (Minten and Forsyth, 2014). In addition, it has been widely publicised, on the shortage in skills (Tiwasing, 2021) specifically in technology (Newton, 2020) this however, still requires further empirical examination within FE.

It is evident that wearable technology is becoming integrated within the student experience through the application of blended learning approaches, but is not without threats to its continued evolution in uses, such as lack of understanding and knowledge surrounding use and capabilities, being used for what built for or fit for purpose, being examples highlighted in the review of the literature earlier (Haugen, Ask and Bjoerke, 2012; Rasheed, Kamsin and Abdullah, 2020). Changes to formal education within this sector continues to evolve and the need to understand what and how wearable technology is involved is needed, including, perhaps a more agile approach to evaluating its impact (Evmenova et al., 2019). Despite the growth in the use of wearable technology, currently there is an absence of a credible conceptual framework for how wearable technology is used in football educational settings. In addition, our understanding of how this technology is deployed and employed in education environments is even less understood (Bower and Sturman, 2015; Attallah and Il-Agure, 2019).

To be able to plan, design and construct effective strategies and models in the use of wearable technology in FE, there first needs to be an understanding and identification of the use of wearable technology in the context of Football in FE and HE settings in the UK. The current study, therefore, aims to identify the related settings that are exposed to the use of wearable technology, what type of technology is being used and who is using it. In addition, the extent of use of wearable technology within these settings identified. Categorise what the technology is being used for, is it for performance, education or both and how it is being used within each setting and in each category.

4.2 Methods

4.2.1 Participants

The participants for this study (n = 113) were initially recruited via a series of social media posts (Figure 2.) between January to March 2020. To aid recruitment a poster advert was purposely emailed to an extensive list of contacts within the football and post 16 education provider industries which the researcher had accumulated over a 15-year professional career (appendix 3.). Additional promotion for the study was established by the lead researcher disseminating the study protocols to heads of sport in FE, following the delivery of a PowerPoint presentation to the Association of Colleges (AOC) ((appendix 4). To take part in the study participants had to confirm they were over 18 years of age and had read and gave prior consent to participate in the study (appendix 5.). The study had gained ethical approval from an institutional review board at Liverpool John Moores University (LJMU). Participants were required to confirm that they were involved in a football related context, FE or HE environment in the UK and were informed they could withdraw from the study at any point. Participants who did not meet the eligibility criteria or conform to the consent statement were excluded from participating.

Figure 2. Poster advert for study promoted via social media twitter and Linkedin

4.2.2 Procedure

The on-line survey consisted of a series of blended questions that included multiple choice, Likert scale and free text questions. Multiple choice questions was chosen to provide contextual comparison between respondents (Cromley and Azevedo, 2011), the Likert scale providing unmistakeable clarity of measurement in answers (Maurer and Andrews, 2000). The inclusion of free text answers was included to allow participations the opportunity to provide more depth and scope for participant to share personal opinions to compliment the quantitative responses (Wright, Atkins and Jones, 2012). This inclusion of qualitative data component within the questionnaire enabled participants to become more involved by being able to comment on own individual experiences from the many diverse settings and industries included in the survey, these being football, FE, and HE environments .

To ensure suitability, validity and relevance of the questionnaire a series of pilot testing was carried out prior to the launch. There is much support for conducting a pilot study to ensure research has a scientific rigour (Hassan, Schattner and Mazza, 2006) and this approach is one that is common practice in the wearable technology industry (Baldassarre et al., 2020). To help with this, three industry experts from FE, HE, and the Football industry took part and provided feedback on the content and structure of the questionnaire. This also benefitted the study as it ensured that no biases from the researcher influenced the content and direction of the study. Following minor amendments, further testing and review, the industry experts confirmed the suitability of the questionnaire. Subsequently, these experts were requested not to take part in the study further and agreed not to complete the actual questionnaire once launched.

The agreed and final version of the on-line survey was administered through (LJMU) Joint Information Systems Committee (Jisc) online Survey. This system provides an automatic secure storage facility to store participants responses. Having previous applied experience of similar approaches aforementioned in my self-evaluation, has enabled me to use the transferable skills gained in this current study.

The online survey when launched was advertised via social media posts on Twitter, LinkedIn and Jisc participant recruitment portal, these consisted of the poster advert (Figure 2) further supported by LJMU and the Football exchange further advertising with a direct link to the online questionnaire (appendix 6.). In addition, the AOC advertised across their organisation and associated contacts (appendix 7.).

Potential participants after reading the advertisement poster were then directed to the anonymous online survey via the link displayed on the poster advert. On landing on the study page, they would then first have to confirm they were over 18, any who did not then the survey would end there. Once they had confirmed age, then a screen would display the participant information sheet, at the bottom of this page participants were then asked to continue reading and answer the following statement *"I have read the information sheet provided and I am happy to participate. I understand that by completing and returning this questionnaire I am* *consenting to be part of this study and for my data to be used as described in the information sheet provided" please answer to confirm you have read the statement and agree to it".* If they agreed to it and answer yes, when they then press next, this would navigate them to the start of the questionnaire, if they selected no then the survey would end there.

The survey consisted of 25 questions (appendix 6.) that were spread across four sections as follows:

Section 1. Asking the participant about background and experiences of wearable technology.

Section 2. Then questions asked about their role and place of work, this then branched out to a different set of questions that related to their place of work that they worked in, to determine the extent of use across the settings. These being Education and Football industry, this was needed as both industries have different departments. FE and HE are similar in that they are both within the Education industry and similar in structure therefore these were grouped together so that Football and Education industries could be compared, without needless repetition and to ensure coverage across all settings.

Section 3. Based on previous answers, questions then asked about the type of wearable technology being used, what it was being used for, specifically, performance, education or both. The survey then branched out further to question more specific on use for performance and education purposes. Finally, in this section, asking to highlight what was being measured when using wearable technology.

Section 4. Focused on the logistics of use, asking who was using, who managed and how, including data collection, analysis and modes of communication of results, from using wearable technology. Finally, participants were asked to complete a further free text question on their opinion on how wearable technology could be used to improve football education specifically feedback and communication. The data was then stored for later analysis once the study closed.

4.2.3 Data analysis

Following download of the completed survey responses (n = 107) the multiple response questions and Likert scale responses were subject to basic descriptive statistical analysis. The free text questions were downloaded on to an electronic notepad application and read and re-read until a comprehensive understanding of meaning was established. The verbatim responses, key words and phrases were then subject to a series of first cycle coding. A second cycle of qualitative content analysis was then applied, and key words were categorised into frequencies and percentages and are reported in the section below. The triangulation of descriptive, quantitative data and qualitative free text responses was applied to provide a more comprehensive and detailed analysis of the survey responses.

4.3 Results

4.3.1 Section 1

Of the 107 accepted questionnaires, 90% of respondents were male and 10% female. When performing analysis for their own personal use the study found that 91% of all responses had used wearable technology in the last 2 years and 86.1% were currently using (Figure 3). Wrist type devices were heavily favoured 60.5% over all other types of wearable technology (Figure 4). Apple watch being the most popular used with 36.6% of users selecting this form as their most preferred over all other types of wearable technology listed (Figure 4). Analysis of use found that 78.2% used to monitor their own exercise (Figure 5) and 78.2% monitored progress over time, 85.2% used at least 1-3 times per week and 53.5% used every day.

Figure 3. Personal experience in the use of wearable technology

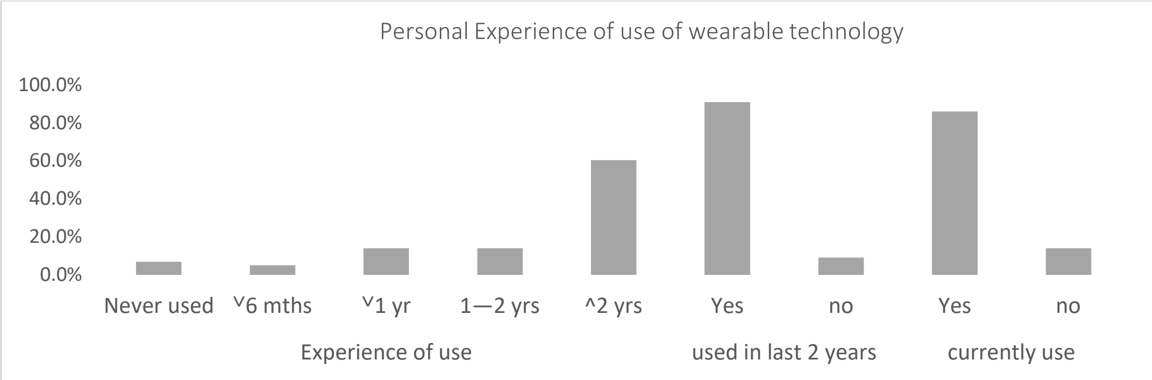


Figure 4. Type of wearable technology used for personal use

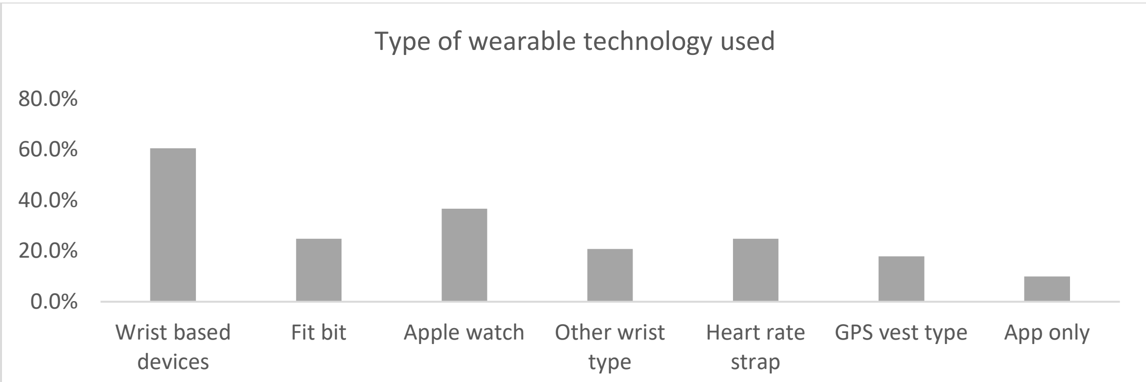
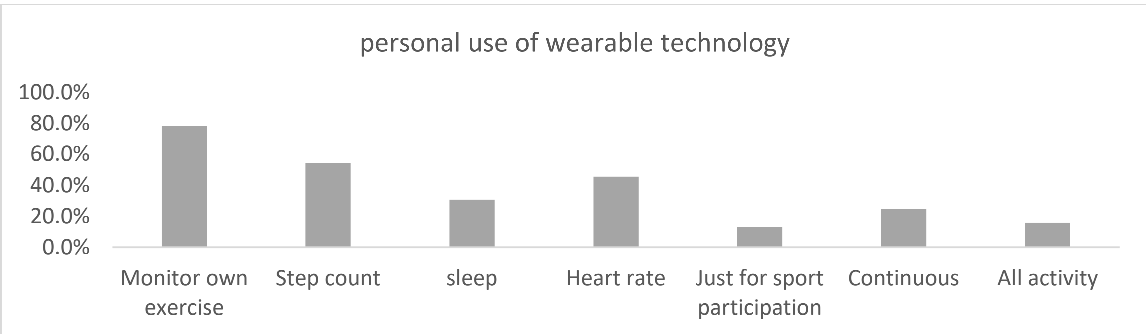


Figure 5. What users monitor with wearable technology



4.3.2 Section 2

Settings within education and football industries accounted for 48.2% and 45.4% respectively, of these 14.9% FE provider not a college, 22.6% College and 10.7% University settings (Figure 6.). Football academies 28.6% and other football settings 16.8%. Roles across all settings resulting in a similar spread of lecturers, Coaches and performance staff, with Performance staff highest with 36.9%, Coaches 27.4% and Lecturers 26.2% (Figure 7.). In terms of departments within the different settings, within education they have competitive teams similar to those in the Football industry both have performance. Results demonstrate that both use differently within this departments (Figure 8). This is reflected further in the data presented (Table 1), that appear to show Football always use wearable technology more on average 25.5% than education 9.2% across the departments selected. Nearly half 48.3% either occasionally or never use in Football settings within their education department with only 6.7% stating they always used (Table 1).

Figure 6. Type of setting in Education and Football industry

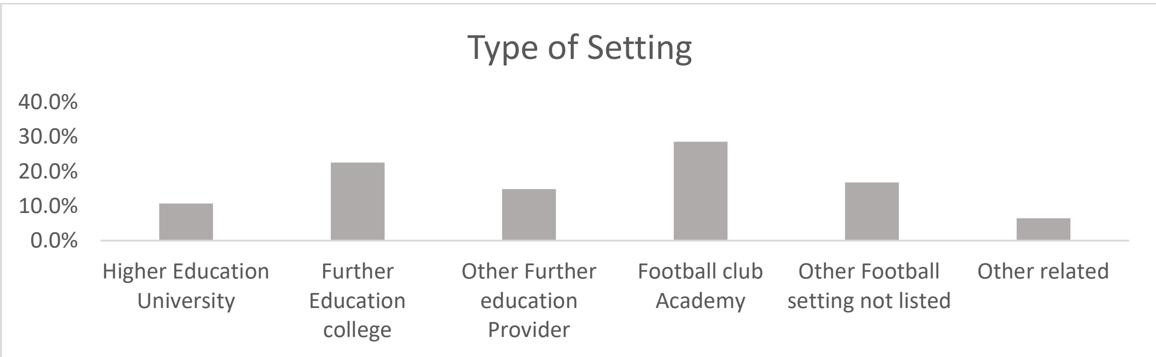


Table 1. Use of wearable technology within departments across Football and Education settings

Setting	*Department*	*Always*	*Frequently*	*Occasionally*	*never*
Football	Senior	31.7%	25.4%	20.6%	22.2%
Football	Coaching	24.6%	37.7%	19.7%	18.0%
Football	Sport science	43.4%	24.5%	13.2%	18.9%
Football	Medical	25.8%	37.1%	12.9%	24.2%
Football	Analysis	21.0%	19.4%	33.9%	25.8%
Football	Education	6.7%	5.0%	48.3%	40.0%
average		25.5%	24.9%	24.8%	24.9%
Standard Deviation		0.12	0.12	0.14	0.08
Coefficient of Variation		47.43	48.93	55.80	32.20
Education	Football	14.8%	25.9%	37.0%	22.2%
Education	IT	0.0%	21.7%	30.4%	47.8%
Education	Across Sport	11.1%	29.6%	44.4%	14.8%
Education	Teaching	10.7%	35.7%	42.9%	10.7%
average		9.2%	28.2%	38.7%	23.9%
Standard deviation		0.06	0.06	0.06	0.17
Coefficient of Variation		69.65	21.03	16.48	69.72

Figure 7. Role across all settings

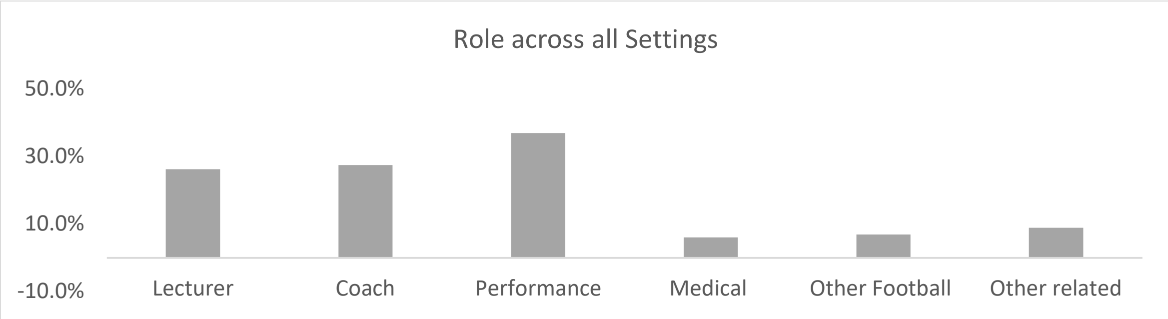
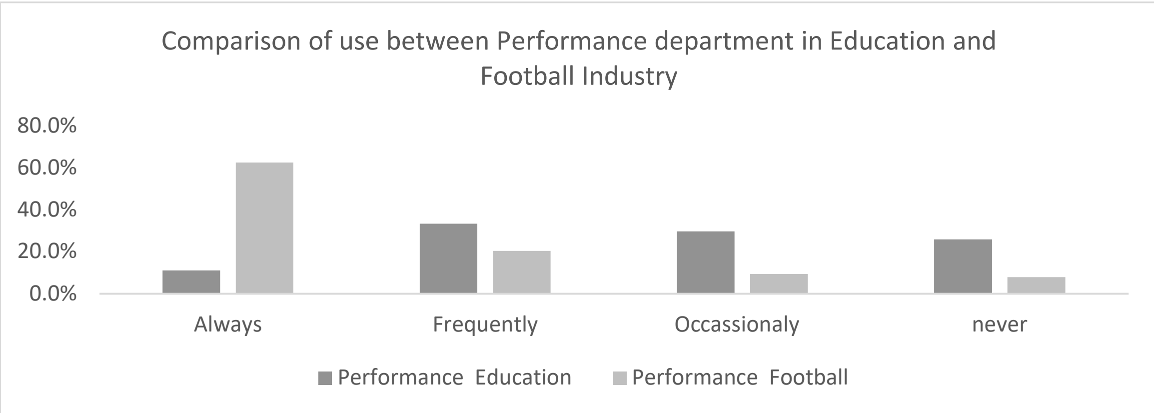


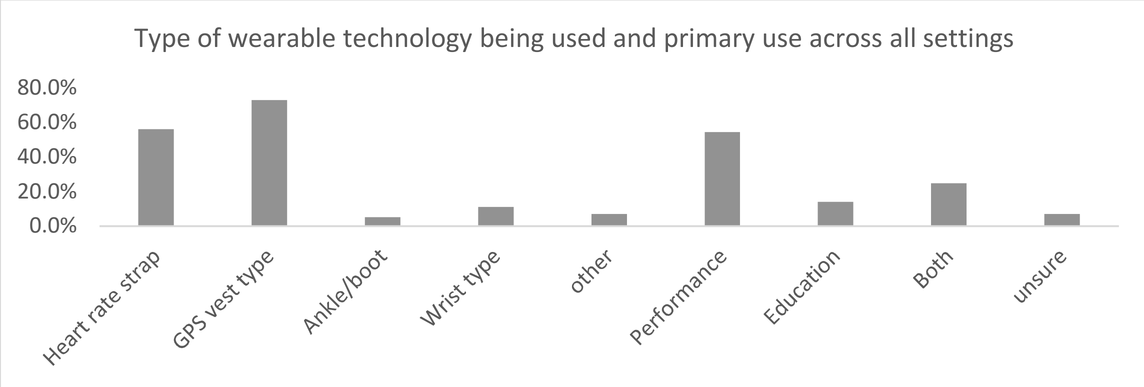
Figure 8. Performance department comparison



4.3.3 Section 3

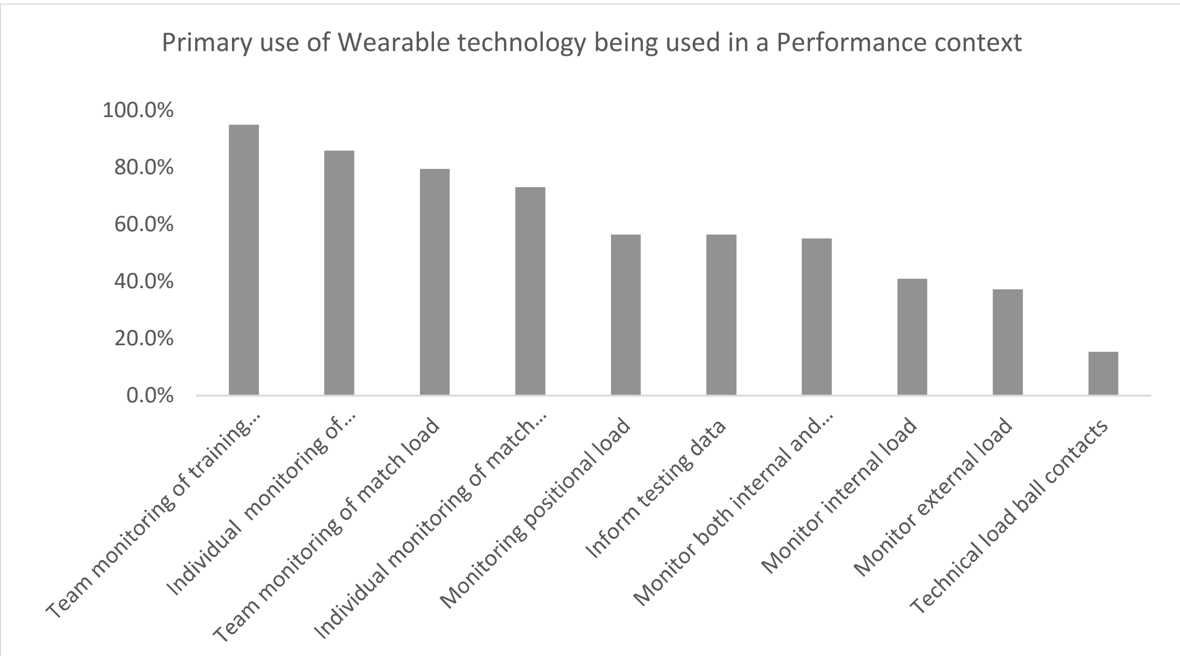
GPS vest type devices proved to be the most popular used 73% closely followed by Heart rate strap types 56% (Figure 9). In terms of users 64.3% used primarily for team or squads, 28.6% were for single user use and 22.4% for group or multiple user use. Across all settings most use for performance 54.5% compared to just 13.9% for education. However, 24.8% stated that they do use for both Performance and education.

Figure 9. Type of wearable technology being used and primary use



When used primarily for performance across all settings, prescription of and periodisation of training were used more often 77.9% and 81.1% respectively than for coaching 52% and tactical 45.1%. Benchmarking of physical performance scored 77.2% however, this is not conducted as regularly as all the others listed. Deeper analysis from questions relating to what used for are further presented in (Figure 10). Team monitoring of training 94.9% and match load 79.5% being the most used with technical 15.4% the least.

Figure 10. Use of Wearable technology in performance context



When used primarily for education across all settings student learning experience accounted for 75% of what primarily used for, the next most popular being coach education 58.3%, use in Literacy and Language being the least used 2.8% (Figure 11.). A further analysis of this, illustrated in (Table 2). Shows that wearable technology is being used when relevant to the mode of study 22.8% average more than at other times and is mostly used in developing understanding over specific skills (Table 2).

Figure 11. Use of Wearable technology in Education context

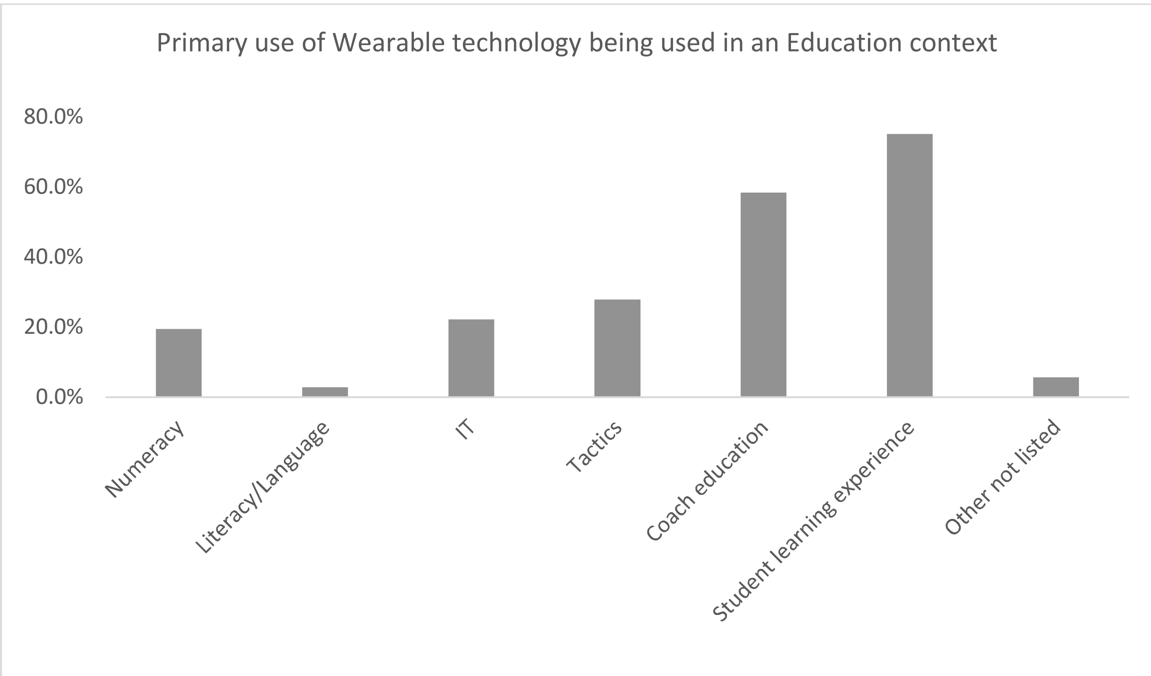
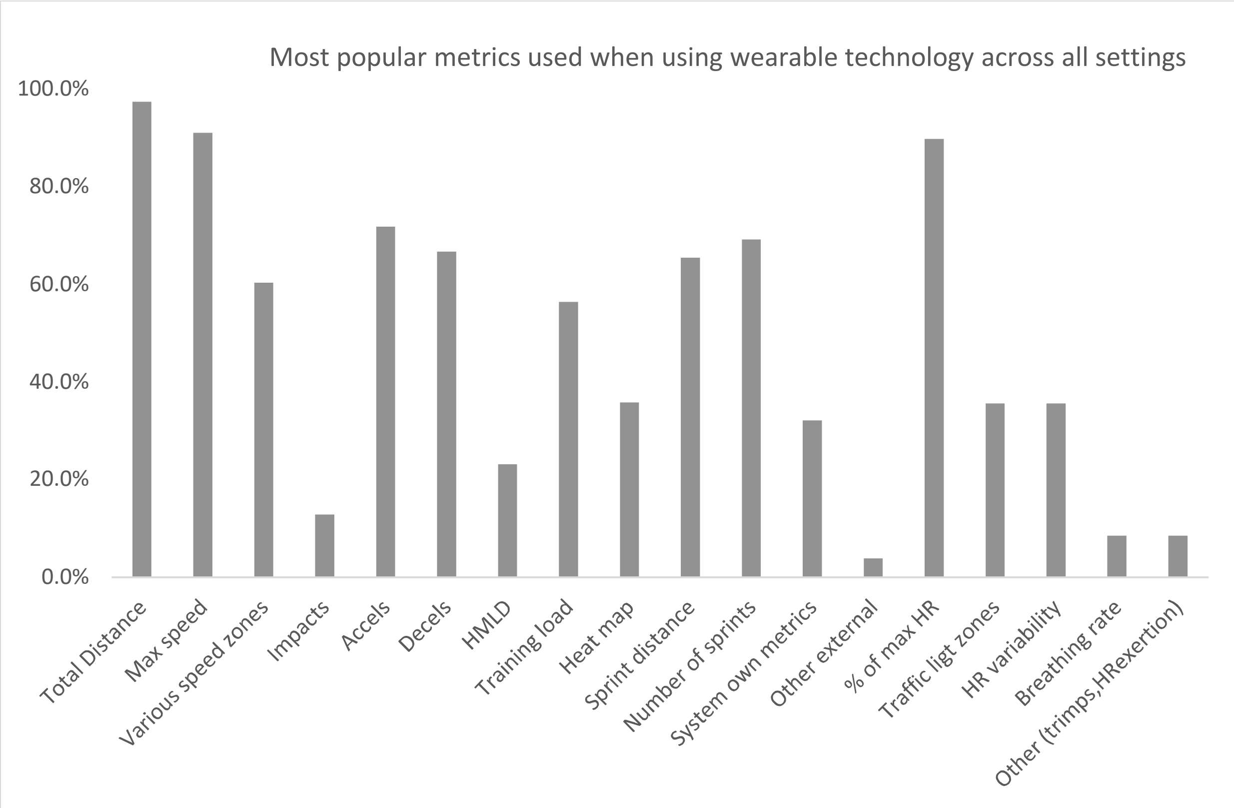


Table 2. Amount of use of wearable technology in an educational context

AREA OF EDUCATION	ALWAYS	FREQUENTLY	OCCASIONALLY	NEVER	WHEN RELEVANT (MODE OF STUDY)
Develop understanding of physical outputs	20%	17.5%	32.5%	0.0%	32.5%
Develop understanding of physical requirements	15%	12.5%	30.0%	5.0%	37.5%
Inform for a student coach understanding	18%	7.5%	25.0%	15.0%	35.0%
Develop math/numeracy	3%	15%	27.5%	42.5%	12.5%
Develop IT skills	3%	10.0%	37.5%	37.5%	12.5%
Other subjects not listed	3%	6.9%	13.8%	69.0%	6.9%
average	10.2%	11.6%	27.7%	28.2%	22.8%
SD	0.08	0.04	0.08	0.26	0.14
COV	80.91	36.40	29.08	93.44	59.58

Results of the types of metrics used for measurements fell into three distinct categories these being internal Load derived from Heart rate type devices 62.9%, External load derived from GPS type devices 80.4% and tactical being derived from ankle or boot type fitted devices 5.2%. On more detailed analysis of the types of metrics presented in (Figure 12). For external load Total distance 97.4% followed by Maximum Speed 91% were the most used and for internal load measure percentage of maximum heart rate 89.8% was most used (Figure 12).

Figure 12. Metrics most used when using wearable technology across all settings



4.3.4 Section 4

Across all settings sport scientists 55.1% followed by 33.7% Lecturers are the main persons who collect and manage the data from wearable technology (Figure 13). The majority 51.5% downloaded data for analysis after activity 7.2% performed this during activity and 41.2% performed both. In terms of how data collected 49.5% use a docking station, 22.7% via a USB connection whilst 22.7% perform via a wireless type connection. Collection of data for analysis performed on the same day in 78.5% of all responses and communication performed on the same day in 73.4% across all settings. In terms of communication of the data, via Computer or other type of display screen was most popular 69.1% with paper form the second most popular method 41.2% (Figure 14). Communication was directed to Participants 70.1%, Coaches 69.1%, Lecturers 20.6%, Heads of education 4.1%, and Heads of performance 37.1%, sport science staff 51.5% and medical staff 46.4%. This was primarily to feedback on performance

83.5%, to monitor training load 59.8% and for educational purposes 42.3%. The displaying of data was evenly spread across open 49.5% and private 50.5% methods of communication and the most popular method to display was inside changing rooms on the wall 38.3% (Figure 15). Responses to the challenges faced with wearable technology resulted in Reliability and accuracy being the most popular response 59.3% with the next closest being understanding of analysis 34.9% (Figure.19).

Figure 13. Person in charge of management and collection of data from wearable technology across all settings

Figure 14. Method of communication of data and who communicated to.

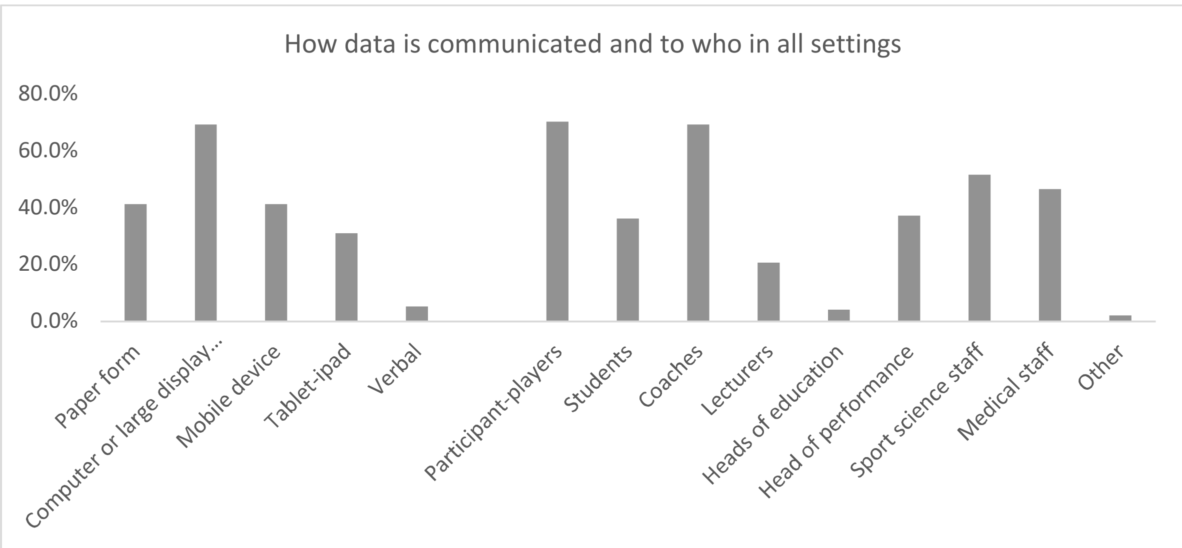


Figure 15. Display of Data from wearable technology in football and education settings

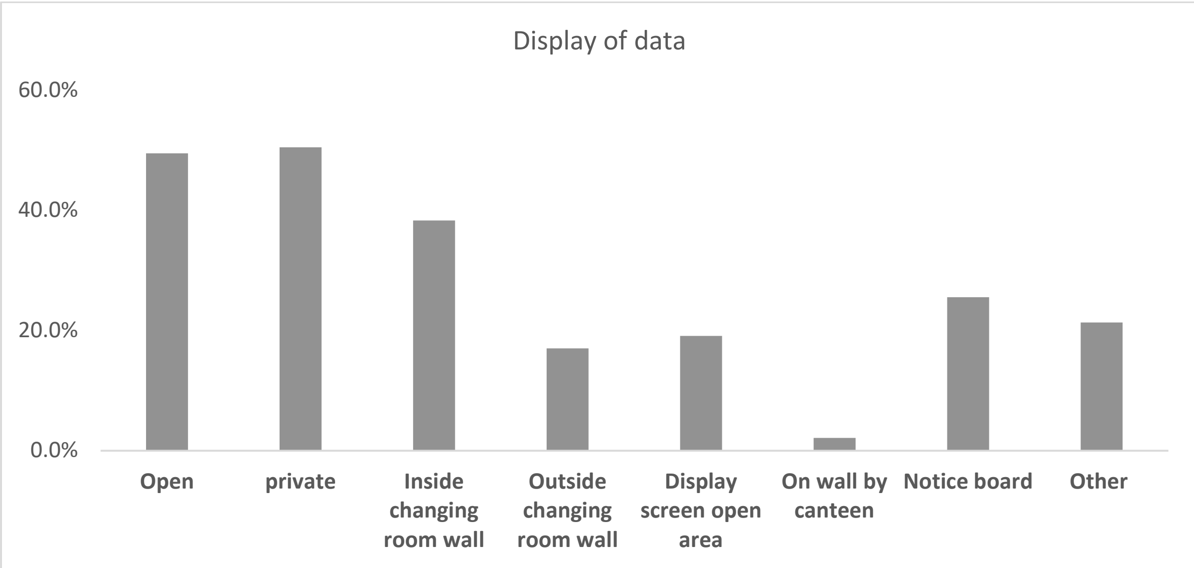
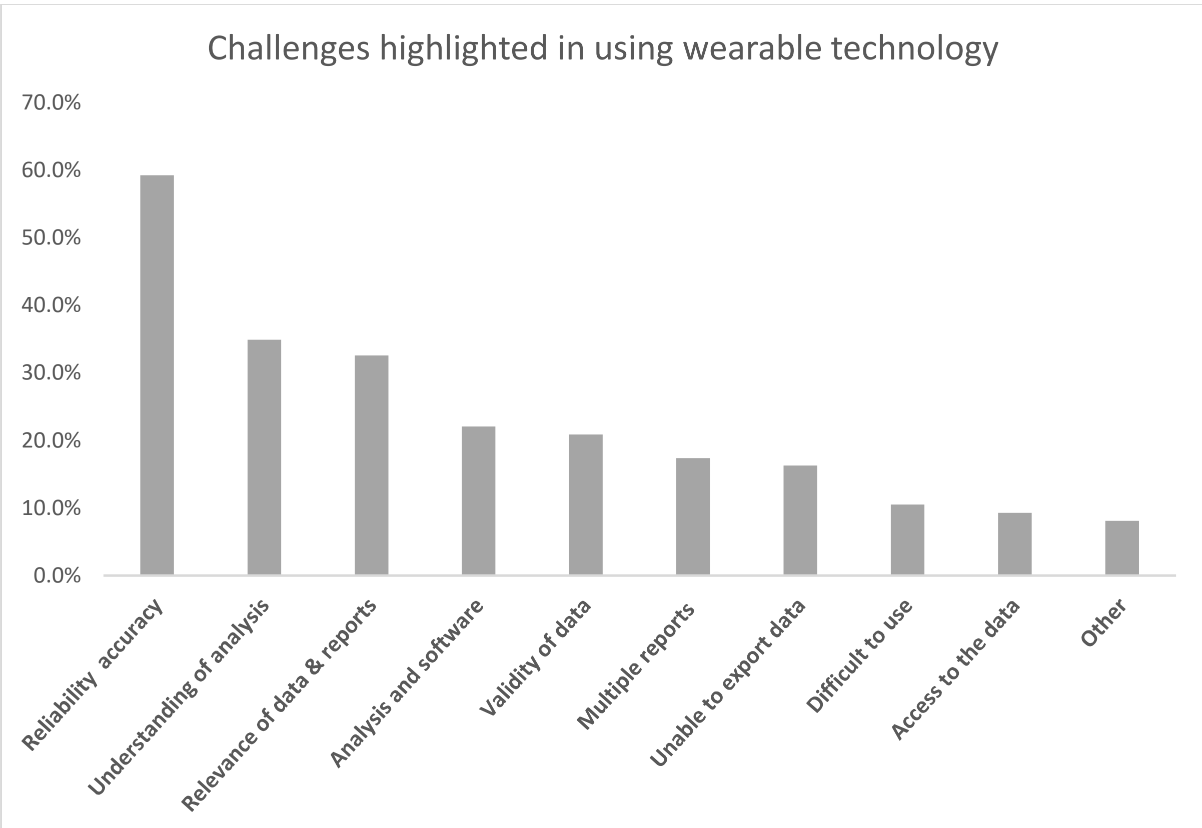


Figure 16. Challenges faced with wearable technology



The final question of the survey asked participants to provide an answer to the following free text question: "*In an ideal world how would you like to see wearable technology used to improve football education specifically communication and feedback*". There were in total 78 responses of which 66 were selected for analysis that met the question criteria. Answers provided were grouped in to four categories being: improve 16.67%, Communication 27.27%, Feedback 48.48% and Miscellaneous 7.58%. These were then broken down further into a further seven categories giving a total of eleven categories (Table 3.)

Table 3. Categories from free text question including an Example Response for each

Category	**n=**	**%**	**Example Response**
Improve	11	16.7%	Integrated Internal and External Load Monitoring
Communication	18	27.3%	Better Communication Between Departments
Feedback	32	48.5%	Catalyst for Conversation
Miscellaneous	5	7.6%	Wearable Technology Is Not Seen as A Priority
Accessibility	19	28.8%	Access to Data
Individual	10	15.2%	More Individualised
Simplify	12	18.2%	Less Black Box
Understanding	19	28.8%	Informed Practice to Informed Theory
Reliability	6	9.1%	Consistency
Ownership	4	6.1%	Student Ownership of Data
Stakeholders	11	16.7%	A Multi-Disciplinary Team

When broken down into these further categories in addition to feedback 48.5%, Accessibility and Understanding were the most popular followed responses 28.8% for both, closely followed by Communication 27.3% (Table 3).

4.4 Discussion

The purpose of this study was first to establish if and what wearable technology is being used in football further education (FE) and higher education (HE) settings in the UK. It is clear from the findings of this study that wearable technology is being used across FE and HE settings and is predominantly reflective of that used in the football industry being GPS vest and heart rate chest strap types.

By first gaining background information on those completing the survey helps to gain an understanding, on participants experience and relationship in context to the survey they are completing (Harcombe et al., 2011). The demographic for this current survey shows the vast majority, some 91% of all respondents having at least two years' experience in the use of wearable technology and of this 78.2% had direct personal experience in the use of wearable technology in relation to physical activity. Having such a high number of responses with a considerable length of time in the use of wearable technology is of added value as demonstrates the depth and breadth of experience participants have, that is directly related to the survey (Baxter and Jack, 2008; Reybold, Lammert and Stribling, 2013).

The two sectors targeted in this study reported an even distribution of responses between education 48.2% and football 45.4%, there was 6.49% that were a mixture of related settings that whilst included components of education and football these did not fall directly into any one setting. Examples being, health and wellbeing provider (n=1), sports consultancy (n=2), multi sports FE provider (n=4). One of the main findings of this current study was that it identified subcategories within each of the two industries, education with three, these being, HE, FE colleges and other FE providers. Football industry with two, these being football clubs and football academies with some of these academies housed within professional clubs. FE accounted for 66.1% of the settings identified, these being, FE Colleges, football academies and other FE providers, having such a high percentage of responses across this sector will further help in gaining an overview of use across FE.

The largest provider in the UK FE sector is colleges, with over 290 colleges in the UK (AOC, 2019), then there are over 72 professional football clubs in England alone, that have academies found in the professional game, governed by the premier league and The FA (Tears, Chesterton and Wijnbergen, 2018). These providing FE in the form of the newly introduced Sporting Excellence Professional Apprenticeship (SEP) being an updated scheme and launched for the 2019/20 season (LFE, 2020), similar to the recently revamped BTEC suite of qualifications, extensively delivered across FE colleges (Pearson, 2019a) and finally other FE providers. These other FE providers consisting of an ever-growing number of companies also termed Independent Training Provider (ITP), that provide education alongside playing football, similar to those found in the football and education industries. These ITPs range from large national coverage companies (SCL, 2020), to individual local companies including those set up by ex-professional players, many of these being unregulated, therefore, it is difficult to determine actual numbers. However, a large number of these ITPs fall under the umbrella of the Association of Employment and Learning Providers of which there are over 900 members (Pember, 2018). In view of this, it would appear that these ITPs are in fact a large contributor within this sector and having an education component such as BTEC, therefore need to be investigated further. Moreover, that this further highlight this being a much under researched area that needs to be investigated.

Smaller ITPs, have grown exponentially in recent years and this looks set to continue as funding for vocational type qualifications that display an entry route to employment is increased

(Education, 2015). Supported by Government, following the much publicised Wolf Report (Wolf, 2011) that reviewed vocational education and training provision specifically targeting post 16 education and training and routes to employment (Ewens, 2012). With over 12,000 FE qualifications available in the UK, the Government has begun to streamline these to increase the quality and therefore it is hoped, the employability of students (Gambin and Hogarth, 2016; Foster and Powell, 2019). This has been observed within the football industry with the recently reformed Apprenticeship programme also termed SEP delivered in academies and the BTEC delivered in FE colleges and ITPs. Along with this, recently announced by the Government that with the restrictions being imposed to FE college based learning, that FE training including apprenticeships will be accelerated and now look to guarantee places for all students seeking to enter, in line with their earlier introduced levy (Gambin and Hogarth, 2020).

The roles performed across settings of respondents, fell into three main categories being Lecturers, coaches and performance staff. There is nothing new in the roles being performed in identified settings as these have been described in the earlier review of literature in chapter two and previously established (Haugen, Ask and Bjoerke, 2012; Read et al., 2018; Stonebridge and Cushion, 2018; Buchheit and Carolan, 2019). In addition, this current study has identified that the use of wearable technology across FE is comparable with use in the football industry as follows; The type of wearable technology being used predominantly GPS vest type and Heart rate chest strap type devices (Akenhead and Nassis, 2016), in a performance context (Malone et al., 2019) with teams and squads (Akenhead and Nassis, 2016). This is of benefit, as experience in the use of similar wearable technology to that used in the football industry would enable students to transfer the necessary skills gained in education when employed in both the education and football industries in the use of such equipment, resulting in enhancing their employability. Furthermore, would also benefit those that are fortunate enough to progress in a professional playing career as have experience in the use along with quantifiable data as used in the professional game (Akenhead and Nassis, 2016).

However, an more comprehensive understanding, surrounding the technology such as that described in the review of the literature in chapter two, along with the metrics being used and meaning, would be more beneficial in an educational setting to educate in.

Early in the survey respondents were asked what type of wearable technology they used for personal use, with the vast majority opting to use wrist type devices over the GPS vest or Heart rate chest strap ones. Whilst it is understandable that a general consumer would choose the convenience of a wrist type device over other type of devices, under football regulations these are prohibited for use and only those that are deemed safe to use (Brud, 2017). Its inclusion for discussion here is borne from the earlier review of the literature, wrist worn technology specifically consumer ones are markedly different from those used in elite sports such as football (Mencarini et al., 2019).

Being seen as unreliable and poor accuracy of many consumer devices is still commonplace (Haghayegh et al., 2019) and this could explain one reason as to why there is resistance to using wearable technology in an educational context. It could also explain the largest 59.3% of responses identifying reliability and accuracy as being the biggest challenge being faced with use of wearable technology (Figure 16).

Football industry settings use wearable technology far more frequently across all departments, in contrast, when wearable technology is used solely in an education orientated environment, it is deployed less frequently than in a football one. Being predominantly used to enhance overall student experience over any specific subjects and only when relevant to a unit or mode of study. It could be argued that this identifies a lack of engagement with the potential of technology being used, as previously highlighted in the review of the literature in chapter two.

Including, the lack of engagement from academia with the technology (Bower and Sturman, 2015; Attallah and Il-Agure, 2019) and supported further in other reviews (Harper, 2018) including within sport (Luczak et al., 2019) and specifically in the aforementioned professional football academies in the UK (Jones, 2019a) is a challenging prospect.

It has been well documented within the scientific literature, that when wearable technology is developed and refined within specific educational programmes, these result in positive outcomes in coach education as well as increased teaching and learner engagement (Dray and Howells, 2019; Evmenova et al., 2019; Turick, Bopp and Swim, 2019). As previously described, educational environments appear to use wearable technology similar to how it is used in football (i.e. performance), as responses revealed the use for performance was 54.5% compared to just 13.9% for educational use. Reasons for these findings could include a lack of understanding of the capabilities of wearable technology (Crook and Gu, 2019; Goad et al., 2019), lack of supportive evidence in coach education (Cushion and Townsend, 2019), resistance to change (Albion et al., 2015), misuse and apathy (Ertzberger and Martin, 2016; Jones, 2019a).

Employer led models (LFE, 2020) are a welcome introduction into football industry, as students embarking on a career in football clearly need to understand a multitude of components that are involved in the sport and increase their employability prospects (Hall, Cowan and Vickery, 2019). Furthermore it is well established that players graduating in professional football club academies less than 1% go on to play professionally (Godfrey, 2017). Indeed, co-collaboration when employed, can be successful, specifically with sport such as football, and education and new technology (Armenteros et al., 2019). This highlights the need to have a better understanding of the complex interactions and relationship between education and performance, as there is some evidence that a disconnect between the two exists.

An interesting observation was that when it came to who performed the collection of and management of data across all settings 25.5% were internship and student placements. It has been previously mentioned in the review of literature (chapter two) that the majority of students are not prepared to work in the industry (Buchheit and Simpson, 2017), or achieve a successful transition from FE to HE (Peake, 2018). This, therefore, needs to be further explored, where undertaking tasks as part of an internship or student placement, to determine if it is beneficial for both the student and the organisation. Additionally, that these should include all stakeholders such as lecturers and students (Ertzberger and Martin, 2016; Kinney et al., 2019) as these directly interact with all components. A good related example when all stakeholders are not consulted, where educational establishments, like general consumers, have purchased equipment not fully understanding the specific uses or potential uses and thus being ineffective (Yoon, Ho and Hedberg, 2004; Bower and Sturman, 2015; Engen, GiÆVer and Mifsud, 2018). It could be argued further that the technology is not able or suited for this type of use and that a new approach is needed to find a solution that is fit for use and meets the requirements and needs for all stakeholders.

Measurement taken and the type of metrics being used was similar across all settings, this is perhaps to be expected given that education and football industries are employing similar wearable technology and is in keeping with the type of metrics used in football (Malone et al., 2019). Regarding the communication of data (Figure 15), this was performed equally both privately and openly, displaying data on noticeboards and display areas including changing room walls. This latter point is concerning, especially as privacy and ethical issues are becoming more prominent. The visualisation of data presented some surprising findings, specifically that data is communicated and displayed in paper form (Figure 14), on a changing room wall 55.3% (Figure 15). Given that the technology being used is sophisticated, it appears somewhat counterproductive that it is not communicated technologically, say in the form of a mobile device such as a person's smart phone, a method that has started to demonstrate some success when used in FE (Bower and Sturman, 2015), including being able to support students better and improve learning, without the need for any additional reliance on staff (Evmenova et al., 2019).

The final question of the survey required respondents to comment on;

"*In an ideal world how would you like to see wearable technology used to improve football education specifically communication and feedback.*"

What was useful in allowing for free text responses was that respondents were able to expand on the answers they gave. An example in the category improves 16.7% was to have "integrated internal and external load monitoring". Feedback receiving 48.5% almost half, of all responses, feedback responses related to understanding 28.8% with an example response of "moving from informed practice from theory to informed theory from practice". Simplifying 18.2% (Table 3) the data being produced, and the example response being "Less black box" and communication 27.3%. Similar findings have been recorded in previous studies (Malone et al., 2017; Lacome, Simpson and Buchheit, 2018; Weston, 2018; Thornton et al., 2019). With these being across multiple stakeholders as being a key challenge to its continued and expanding use in football (Malone et al., 2017; Malone et al., 2019; Rago et al., 2019). Specifically, in a football educational environment such as that found in the aforementioned UK academy structure and further supported in a recent study that reported poor feedback and communication being seen as major barriers to continued use (Nosek et al., 2020). This current study has identified that wearable technology when communicated, is to primarily, feedback on performance 83.5%, with it further highlighting that feedback, specifically understanding and simplifying of data are areas requiring further investigation. This could explain why wearable technology appears to have not transferred across equally, for use in education as it is in performance, as being a relatively recent inclusion to sport performance and taking as long as four to five years of continuous use before being able to effectively evaluate its use for performance (Luczak et al., 2019). Along with ever-changing technology that could be seen as a further barrier to its use in education. However, this does highlight the need for further research into its use for education and performance.

In conclusion, this current study has provided an overview of wearable technology use in football related FE and HE settings in the UK. The major headline findings were. Identifying subcategories that form settings within the FE sector delivering a range of formal qualifications along with various levels and modes of participation in football. The type of wearable technology being used reflective of that used in the football industry being GPS vest and Heart rate chest strap types and used more for performance than educational purposes. Visualisation of data from technology predominantly displayed in paper form and large display screens, most popular location to display inside changing room wall. There are large variations to when wearable technology is being used and what for, across all identified settings. Wearable technology needs to be more accessible and individualised, simplifying feedback and communication would help understanding. Similarly with other studies findings (Bower and Sturman, 2015; Attallah and Il-Agure, 2019), further research is required to better understand how wearable technology is being used across the FE sector. Additionally, the differences between these subcategories, and describe and contrast the use for both performance and education purposes. With those identified in this current study being professional football academies that deliver SEP, FE Colleges and other FE providers that predominantly deliver BTEC type courses.

4.5 Limitations

A potential limitation to discuss in this study was the reach of number of participants, by exclusion of advertising through Facebook, which has been reported to enhance the reach to more users (Rife et al., 2016). That said, with over 6,148 impressions of which 303 directly engaged with the first of 6 tweets advertising the survey via Twitter, which extended to a wider audience by receiving 12 retweets and a further tweet by LJMU football exchange further supports the use of social media platforms such as Twitter (Rife et al., 2016), to promote research studies such as the current one. In addition, given that FE, HE and football are fairly large industries, having a limited number of completed questionnaires could be seen as not being representative of the population targeted and therefore a potential limitation to this current study as the sample size being low in comparison to overall size of these industries. However, as detailed in the recruitment process and to add validity to the survey responses, a strict criterion was being used that would be targeting a potentially small population within these industries.

This should be viewed as a strength to the current study in that it has employed a scientific rigor in line with other studies that have investigated areas that are evolving and fast moving such as wearable technology and sport (Luczak et al., 2019). A good example of this is as follows, it is estimated that there are well over 45,000 Strength and conditioning coach members of the National Strength and Conditioning Association (NSCA) in the USA (NSCA, 2019), yet the study by Luckzak and colleagues employed only 113 for their study representing 0.25% of the overall population and this is in keeping with other similar studies (Schaben and Furness, 2018; Kinney et al., 2019). Furthermore, as this is to the researcher's knowledge, the first study of this kind in these settings and the limited literature as highlighted in the earlier review, it would be seen as prudent to focus on the quality rather than the quantity of responses.

CHAPTER 5

Research Study 2 “Look”

The use of wearable technology for performance and education in FE settings in the UK

5.1 Research orientation

The results of the previous study described in chapter four support the original rationale for formulating the research project in that, it does appear that wearable technology is very much underused in Post 16 education, specifically in the FE sector. Given the results of the first study, it is apparent that there is the potential to educate, through better understanding of wearable technology and the data produced from wearable technology in these settings.

With the type of wearable technology used, the deployment and employment of use being mirrored in educational settings as that in a professional football setting, again this latter setting being one that use wearable technology for performance. Whilst the use for performance in a senior professional football setting is understandable, as they are looking to measure and change performance to ultimately win games. These organisations, also tend to have the luxury of support staff who collect, analyse and communicate to players and other stakeholders, as part of normal practices in these environments (Drust and Green, 2013). As previously described, many of these clubs also have academies that deliver post 16 education along with developing a playing career as part of the now well established EPPP (Tears, Chesterton and Wijnbergen, 2018). However, lower down the UK football pyramid, clubs and teams do not have the luxury of this type of support and in many ways this is due to a combination of lack of finances, knowledge, understanding and different priorities (Hossain et al., 2017; Cushion and Townsend, 2019). In addition, being viewed as used for performance, and in many cases the need for external specialists required to deliver, the UK government has recently (2020) curtailed funding for this type of provision (Education and Skills Funding Agency, 2020b). Therefore, FE needs to explore other methods to increase what they are able to offer students in terms of gaining the appropriate level of education and industry related experience, to enable them to progress to HE or direct employment.

Consequently, it is perhaps surprising that in educational settings wearable technology also appears to be used in a similar way to that of the professional game. This use in an educational context, could be due to a lack of understanding (Bower and Sturman, 2015; Sole Blanch, 2020) and this is supported with the findings of study one discussed in chapter four, that reported understanding as being one of the major challenges faced. As such, there needs to be a much clearer understanding surrounding the use of wearable technology within FE settings, specifically the increasingly growing number of ITPs described in the aforementioned study. Therefore, this should be an area investigated further in order to determine the uses in more detail in a football performance and educational context across identified FE settings within the FE sector.

5.2 Introduction

Historically HE, specifically universities, sit at the top of an hierarchal social structure and are considered to be the goal that everyone should aspire to in an academic context (Jackman, 1973). FE colleges and other FE ITPs are also viewed as an attractive route, or an alternative to staying on at sixth form (Peake, 2018). Whether that be through social or attainment factors, are seen as an accessible route to HE or employment as identified in the previous study, whereby the FE sector acting as a conduit (Gartland and Smith, 2018; Spence and MacNamara, 2018). One of the recent developments in this field is the opportunity to gain football industry experience, whilst also studying for a formal qualifications (Harrison et al., 2020), in what has been commonly referred to as a blended learning approach (Braun, 2019).

A hierarchal structure is also reflected within the football industry, and it could be argued that in some clubs at an academy level a harsh ‘dictatorial’ type of regime exists, (Jones, 2019a), and is reflected in both coaching (Hall, Cowan and Vickery, 2019) and surrounding the use of wearable technology (Sewell, Barker and Nyberg, 2012). In consideration of these, there is a need for a different approach to his study to ensure that all voices are heard and any potential biases are curtailed (Hewson, 2017). Examples of these being manifested from previous experiences and early use of a vastly underdeveloped and in many cases a very expensive purchase of technology as detailed in the earlier review of literature. Times have changed, but views of many coaches and lecturers may not (Cushion and Townsend, 2019), as they may not be informed in the recent advances of the last five years. Additionally, experience could be just from personal use, such as some of the inferior wrist worn type devices as reported in study one and review of the literature (Halson, Peake and Sullivan, 2016; Ahmed et al., 2018).

As previously mentioned, very few that participate in football go on to become full time professionals, with very little emphasis or engagement within many full-time football environments to attain success in educational academic qualifications. This emphasis, in part, is mainly due to the pressure on sporting performance (Morley et al., 2014). There has been reports that those that left, aspiring football playing careers, were heavily constrained in gaining future employment or qualifications (Monk and Olsson, 2006). There are studies that have shown that where football performance and education are promoted alongside each other in dual programmes, that these in fact clash, being polar opposites in the fundamental way many football clubs work (Thomsen and Norgaard, 2020).

It is perhaps understandable that a club will focus more on a young player footballing ability, especially if their performance catapults them through the ranks and perhaps even be fortunate enough to represent the senior first team. Then if injured or fall out of favor they are discarded back into the academy system (Tears, Chesterton and Wijnbergen, 2018), where they must try to reengage with the educational component of their career. Some teams employ, with some success, a dual career type course and these have, where run correctly, with buy in from all parts of an organisation, can prove successful in students gaining qualifications and increased opportunities in academia and direct employment. Whereby carefully designed interventions can aid in the development and laying the foundations to a lifelong learning journey (McGillivray, 2006) and more recently reported (Thomsen and Norgaard, 2020).

The aforementioned studies are mainly in the domain of professional football clubs and not the main focus of this research. However, its mention here is worthy to help in understanding the landscape, as many providers in the FE sector tend to try to mirror these professional football clubs. Indeed, many advertise the fact that this is what they are doing, portraying themselves as providing a professional football experience and environment, with the opportunity of gaining industry experience and academic related qualifications. Colleges and more specifically these ITPs identified, that offer playing football alongside gaining academic and industry related qualifications, tend to recruit from a population that have not made it to a full-time professional club. Therefore, their chances of progression to a full-time playing career are reduced even further, than those at these fulltime professional clubs, that's not to say they could not go on to play at a professional level. Yet as previously described, many of these ITPs promote as providing a professional football experience aligned to that of academy football provided by professional football clubs (Godfrey, 2017; Tears, Chesterton and Wijnbergen, 2018). This could perhaps see more of a focus then, on football related performance than education, specifically academic and non-playing qualifications and experiences. Which is somewhat counterproductive given that those enrolling were not seen as being suitable to progress in a full-time professional playing career.

With the rise in the number of ITPS (Pember, 2018) and the trend increasing in recent years (Hodgson and Spours, 2019), the curtailment of subcontracting work (Education and Skills Funding Agency, 2020b), along with these not been regulated as FE colleges are (Ney, 2019), have scarce amount of research. Furthermore, there is a lack of quantifiable evidence to underpin the justification for expansion of this large area of FE, funding is strictly controlled by central government through Ofsted and only recently has the Education and Skills Funding Agency (ESFA) updated its operational guidance document (Education and Skills Funding Agency, 2020a). Here the government state that the priority is to ensure that all learners have a quality learning experience (Education and Skills Funding Agency, 2020a). How that is determined is less clear and without quantifiable data, it is perhaps unclear how ITPs will be able to evidence this. Therefore, the aim of this study is to describe and contrast the current and potential uses for wearable technology in football related FE settings.

5.3 Methods

This study consisted of three convergent parts, an online questionnaire an offline questionnaire and One – One interviews. These adopted a mixed- methods research design, this type of design being suitable as more than just one type of data is required, which will give a deeper insight and understanding of this complex problem (Klassen et al., 2012; Creswell and Creswell, 2017) This convergent parallel design comprised of both quantitative and qualitative data as is reported below:

The quantitative components consisted of an online (appendix 9.) and offline questionnaires (appendix 10). Participants were recruited from an email invitation to a compiled list of stakeholders that was from the researchers own list of contacts from the vast network built over the last 15 years. Despite this sampling frame a strict recruitment eligibility criterion to ensure participants were suitably qualified was applied (appendix 11.). With the second questionnaire and One – One interviews further recruitment was performed employing a purposive and snowball sampling technique (Tongco, 2007; Noy, 2008). This ensured those selected were able to input effectively and had the necessary expertise and knowledge of the research problem under scrutiny.

The qualitative component consisted of one-one interviews with participants. The questionnaires helped to expand on the developing themes and enabled for a semi structured interview style to be employed. The interviews were recorded using an audio device and then transcribed verbatim for analysis using a qualitative coding method. This was in two parts, the first were those that directly related to the research questions that were presented in the questionnaire and used for the interviews. The second part was any that had not previously been presented and were the result of free expression from interviewees as they were allowed the opportunity to expand on their responses, to allow for more free expression. To ensure suitability, trustworthiness and relevance, the first questionnaire of this study was formed following a series of pilots with a sample of stakeholders within the various industries. There is much support for conducting a pilot study to ensure acceptable levels of scientific rigour (Hassan, Schattner and Mazza, 2006; Hewson, 2017).

This first questionnaire provided anonymity for respondents, thus allowing participants more freedom to express their views and opinions privately, without duress or other external forces influencing their decision making process (Bouchard, 2016), thus minimising potential biases being imposed by others (Jones, Rands and Butterworth, 2020).

On-line questionnaire

This questionnaire consisted of 32 questions (appendix 9.) thus larger than those employed in the previous study detailed in chapter four, this allowed for findings to be explored in more depth. Questions 1- 25 were similar to the first study questionnaire, in that background information of the participant, including experience with use of wearable technology personally and in the workplace. Question 26 was a closed binary Yes/No and was designed to elicit an opinion on the usefulness of wearable technology in various components football and education related areas. Question 27-32 asking participants to provide a mix of one word response and free text, expanding on responses from study one surrounding barriers, concerns and how they wanted to see the use of wearable technology develop in an ideal world.

Offline questionnaire

This questionnaire consisted of eleven questions, the first three to confirm experience and background relevant to the study. Question four had twelve categories asking respondents to select on a scale the degree of usefulness and an additional column for free text (Appendix 10.) to expand on the answer they gave. For this a five-point Likert scale was employed on usefulness (1=not at all useful; 5= extremely useful). These free text answers would help in developing the emerging themes in the One – One interviews. Questions five to eight asking participants to answer questions surrounding how wearable technology changing within their environment, employing a Likert type scale with responses based on impact (very negative; to very positive) benefits (very negative; to very beneficial) more or less (none; to, lots more) in the use of wearable technology in football education. Questions nine to eleven being free text answers to questions surrounding barriers, concerns and how they wanted to see the use of wearable technology develop in an ideal world. The first questionnaire would be then merged with the second to aid in clarifying themes for the One – One interviews.

Semi-structured interviews

The semi structured One – One interviews, were conducted via an online communication platform (i.e., Microsoft Teams) and recorded for transcription and later analysis. Using the respondents completed questionnaire from part two (appendix 10.) for reference to expand on answers provided. As aforementioned the participants for this stage were recruited via; contacted directly from the researcher own network of contacts and from a snowball sampling technique. The themes that emerged from questionnaires would also be used during these interviews, to help stimulate discussion. Additionally, they would also be employed for discussion with the focus group that forms. The interview structure (appendix 12.) continued from part two answers and covered four sections, these being;

a) Background, including about the setting working in (appendix 12.)

b) Usefulness of wearable technology in identified categories,

c) The changing use of wearable technology in the participants setting in an football and educational context,

d) Barriers, concerns and development

5.4 Procedure

The questionnaires were constructed of a blend of questions that included multiple choice, Likert type scale and free text questions, forming a type of triangulation method approach (Kimchi, Polvika and Stevenson, 1990; Wang and Duffy, 2009) . Multiple choice was chosen to provide contextual comparison between respondents (Cromley and Azevedo, 2011), the Likert type scale providing unmistakeable clarity of measurement in answers (Maurer and Andrews, 2000). By including some free text answers would provide more depth and scope for participant to share personal opinions (Wright, Atkins and Jones, 2012), thus providing a deeper understanding than from just quantitative data alone (Harper and McCunn, 2017). This inclusion of more qualitative data within the questionnaire enabled participants to become more involved by being able to comment on own individual experiences from the many diverse settings and industries included in the survey, these being Football, FE and HE. This would also give some context to the developed themes that would be expanded on in the One – One interviews.

The first questionnaire was administered through Liverpool John Moores University (LJMU) Joint Information Systems Committee (Jisc) online Survey, this provided an automatic secure storage facility to store participants responses. Potential participants on opening their email were instructed to read the participant information sheet, they were then directed to the anonymous online questionnaire. On landing on the study page they would then first have to confirm they were over 18, any who did not then the survey would end there. Once they had confirmed age, then a screen would display following statement *"I have read the information sheet provided and I am happy to participate. I understand that by completing and returning this questionnaire I am consenting to be part of this study and for my data to be used as described in the information sheet provided" please answer to confirm you have read the statement and agree to it".* If they agreed to it and answer yes, when they then press next, this would navigate them to the start of the questionnaire, if they selected no then the questionnaire would end there.

The second questionnaire was administered through the researcher in a similar fashion to the first, the main difference being that participants information sheet (appendix13.) now included the request to participating in One – One interviews and a possible focus group, as well as completing an offline questionnaire. If agreed to participate they were then emailed the questionnaire (appendix 10.) to complete and return. Those that agreed to participate and met the study criteria, completed and returned questionnaire, they were then invited to attend an online One – One interview with the researcher. These were semi structured, in that there were the completed questionnaire responses given and themes for discussion to allow for a more natural flow. This was to ensure that each interviewee was afforded the time to discuss around what they felt more important to them in their circumstances.

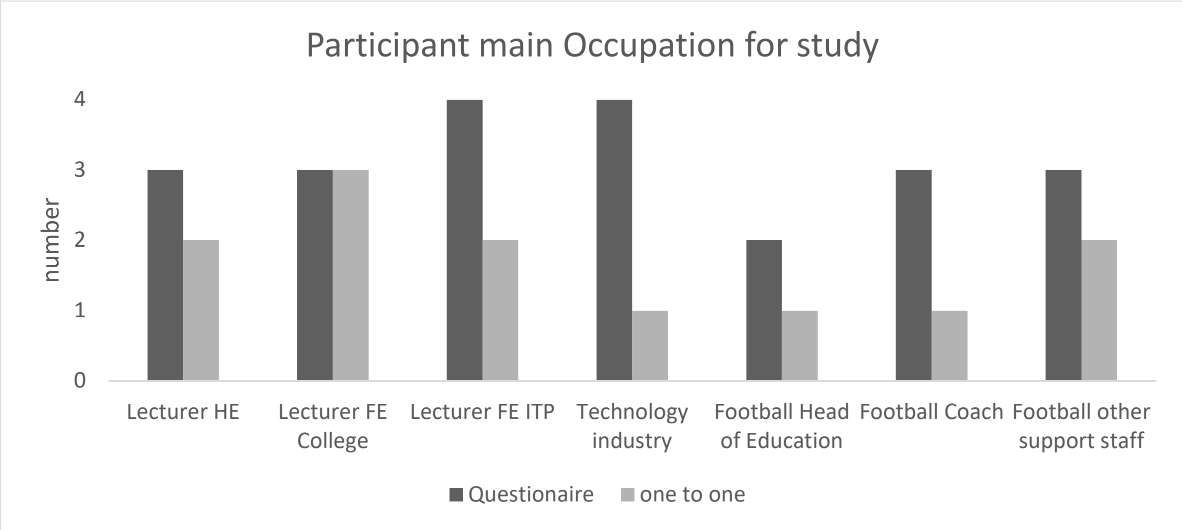
It was important being structured in this way as it ensured continuity and a smooth transition from each study. From first harvesting data from a wider population in study one and then funnelling towards experts in study two leading to the One – One interviews would give more measured and deeper insights expanding on answers and helping with themes being formed. This also ensured an even spread of responses from the identified settings to enable a versus analysis comparing across the identified settings from study one. By including more Likert scale and free text answers allowed participants to expand on the findings from study one. A kind of deep dive, drilling down into the general questions from previous study. Having the researcher monitor responses from those participating ensured that if any setting was underrepresented then the researcher could conduct further rounds of targeted recruitment. By ensuring participants were recruited across all the settings targeted ensured all voices were heard when performing analysis of results, with more of an emphasis on the educational aspects of settings as opposed to the football playing. For forming the themes for the One – One interviews an external verifier was recruited.

5.5 Results and discussions

Results and Discussion

For study two, the first questionnaire there were a total of 22 completed questionnaires that were selected based on the criteria, with the second questionnaire a total of 12 completed questionnaires were selected that met the criterion, ensuring that there was more of a weighting to the education aspect of the research for the One – One interviews. Thus, ensuring that each setting was represented enabling all voices to be heard across the education and football settings being focused on (Figure 17.).

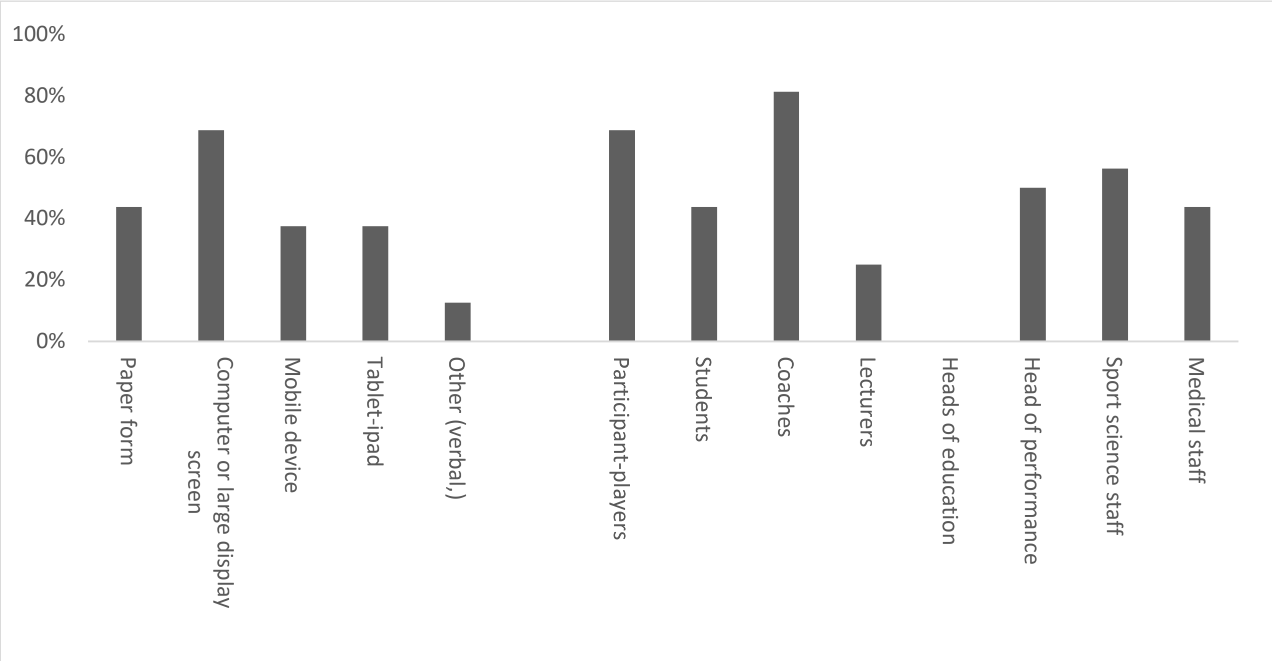
Figure 17. Participants' occupations



Section a) Background, including about the setting working in

Supported the findings from study one and found that 86% (n=19) had experience in use of wearable technology and that 77% (n=17) were currently using, 86% (n=19) used wearable technology weekly. Apple watch being the most popular again used with 36% (n=8) However, this was closely followed by wrist worn Fit bit and heart rate chest straps both 27% (n=6). Analysis of use found that 77% (n=17) used to monitor their own exercise and 64% (n=14) monitored progress over time. When it came to use in the workplace and what was being used, these again were similar to the findings of study one. With wearable technology being used primarily for performance 65% (n=11) and education 11% (n=2). GPS vest type 71% (n=12) and heart rate straps 53% (n=9) were the most popular being used and compared similarly to study one that found GPS vest 73% and Heart rate 56% were being used. Other results were similar findings to study one, for how data communicated and to whom (Figure 18), interestingly heads of education within football clubs that took part reported in no data being communicated to them (Figure 18), conversely, heads of performance was 50%. This would further support the earlier findings that wearable technology is being used more for performance than education within these settings. Furthermore, when data is communicated, 81% coaches compared to 25% lecturers have data communicated to them (Figure 18).

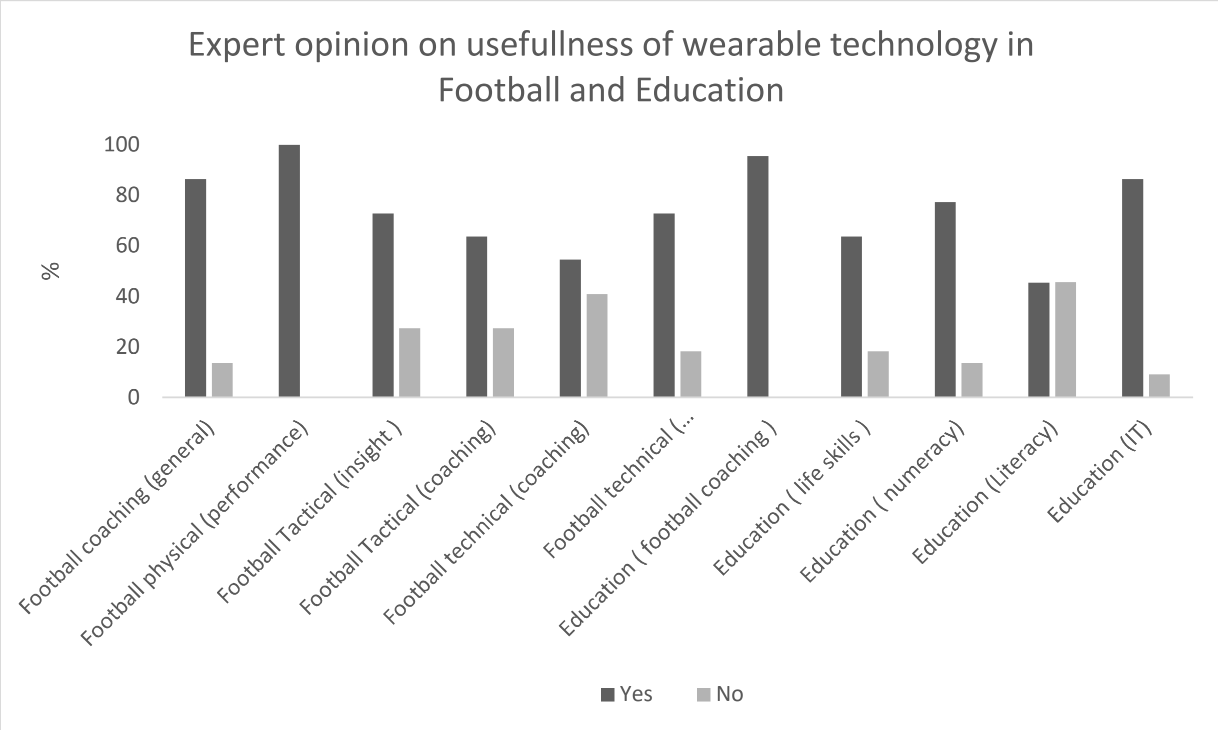
Figure 18. Method of communication of data and who communicated to



Section b) Usefulness of wearable technology in identified categories

In terms of the use of wearable technology, highest in terms of usefulness in yes or no responses with 100% of all responses was use of wearable technology for football performance (Figure 19). Coaching was most popular across both football general coaching 86% and football coaching education 96%. For other educational use, responses were more positive than negative in terms of opinion as to usefulness in other curriculum subjects (Figure 19) use in Information technology (IT) received 86% yes responses, followed by Numeracy 77% and Life skills 64% yes responses. Literacy displayed more negative than any other measure 46%, however, it did have an equal number of positive responses 46% (Figure 19).

Figure 19. Yes or no responses on the usefulness of wearable technology in football and education



When expanded on in the second questionnaire employing a Likert type scale to assess the degree of usefulness Table 4. The majority of respondents stated that wearable technology for football coaching was very to extremely useful highlighting that it was able to

"Provide useful feedback to coaches and players".

Furthermore, most respondents stated that wearable technology is useful for football overall physical performance, was very to extremely useful highlighting that it was able to

"*Gives objective data and outputs that are specific" "Gives an explanation behind performance, eg if a player not doing as well then can look back at data to inform on fatigue and other factors".*

Table 4. Respondent's scale of opinions on the usefulness of wearable technology in various categories listed A-L

		Number of responses					*total number of responses*
		Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful	
A	Football coaching (general training and games)	1		1	4	5	11
B	Football physical (overall performance)	1		1	3	6	11
C	Football Tactical (insight)	1	2	2	1	4	10
D	Football Tactical (positional/team coaching)	4	2	2	1	2	11
E	Football technical (coaching of skills)	5	2		2	2	11
F	Football technical (monitor performance of skill)	5	1	1	3	1	11
G	Education (football coaching)	1		5	2	3	11
H	Education (life skills)		3	1	1	5	10
I	Education (numeracy)			3	4	4	11
J	Education (Language words)		2	3	3	3	11
K	Education (Literacy)	2	3	1	2	3	11
L	Education (IT)			1	4	6	11

When it came to the use of wearable technology for tactical insight in football, respondents were spread across the range but more weighted to very and extremely useful with half of responses in these two categories extremely useful commenting

"Heat maps generated from GPS give positional data and therefore understanding of position based on tactics employed".

In terms of use for tactical coaching in football both positional and team the majority of respondents stated the use of wearable technology was only slightly to not at all useful.. For example below is a quotation to illustrate this point:

"I do not believe the link between technology use and tactics is understood partly due to lack of education of coaches".

This was also reflected in terms of use for technical coaching of skills in football, the majority of respondents providing similar responses stating the use of wearable technology was only slightly to not at all useful. The comment below is evidence of a typical response:

"Technology is unable to identify and/or improve so don't change it if it's working". Furthermore, on use to monitor performance of skill in technical element of football the majority of respondents stated that it was not at all useful. Such as the comment below:

"*Able to create a player without the use of wearable technology".*

This perhaps is further evidence of a lack of understanding surrounding wearable technology uses in football coaching (Nosek et al., 2020) and lack of coach education on how wearable technology can be used to help with aspects of coaching (Cushion and Townsend, 2019).

For use in education football coaching, the majority of respondents stated that wearable technology was moderately useful highlighting

*"The educational aspect of wearable technology is limited in delivery currently but good to show coaches", t*o extremely useful, highlighting *"Can be used as tool to educate potential coaches/students on how different types of coaching and training activities affect physical performance and make coaches aware of how wearable tech can be used to enhance their coaching".*

However, one respondent stated that they considered it was not at all useful because,

"More understanding of how to make it more educational would be beneficial",

thus highlighting, the lack of and need for better understanding. This is in contrast to the earlier findings for use in general football coaching as reported in the previous paragraph that highlighted that majority of respondents felt it was very to extremely useful compared to football coaching education.

In terms of usefulness in education for life skills, the majority of respondents stated that wearable technology is extremely useful, highlighting

"*depends how you link in with a life skills programme*".

When expanded on into other specific subject areas in education, numeracy resulted in all but one respondent stating that it is useful, to very useful, example responses being

"*Can serve as a medium to promote interest in numeracy, which has a tendency to be a very dry subject. By having data from football tends to be better buy in from students*"

and

"able to contextualise data as it disguises the maths to real life and connects with students".
The one respondent that felt it was not useful commenting

"numeracy skills have likely already developed by this time".

This could be true in their individual experience and further investigation confirmed this, as the respondent had worked in just one specific setting with one group of students, these being second year FE students who would normally have achieved an basic understanding of numeracy as determined by gaining the required qualification a General Certificate of Secondary Education (GCSE). This could be viewed again as a lack of understanding of the capabilities of wearable technology in use to help further develop numeracy, specifically, which is football and wider sport industry related (Spence and MacNamara, 2018).

In terms of usefulness in education for Language, again the majority of respondents stated the use of wearable technology is moderately useful stating

"*Understanding of meaning and introduction of new words such as technical terminology"*.

To extremely useful highlighting

"*Able to discuss data with coaches and others*".

That said with some closely related subjects , such as Literacy, there was a much more mixed range of responses, from not at all useful highlighting

"Technology does not help them construct sentences"

whilst at the other end of the scale extremely useful highlighted

"Extends vocabulary and how to put into word transferring skills by putting numbers into written reports".

It is perhaps no surprise that, In terms of usefulness in education for IT*,* all of the respondents stated that wearable technology was useful, highlighting

"besides the obvious in relation to operating software, I think troubleshooting is a key skill often overlooked that this can aid"

Very useful

" Can serve as a medium to promote interest in IT to better enhance students buy in to IT"

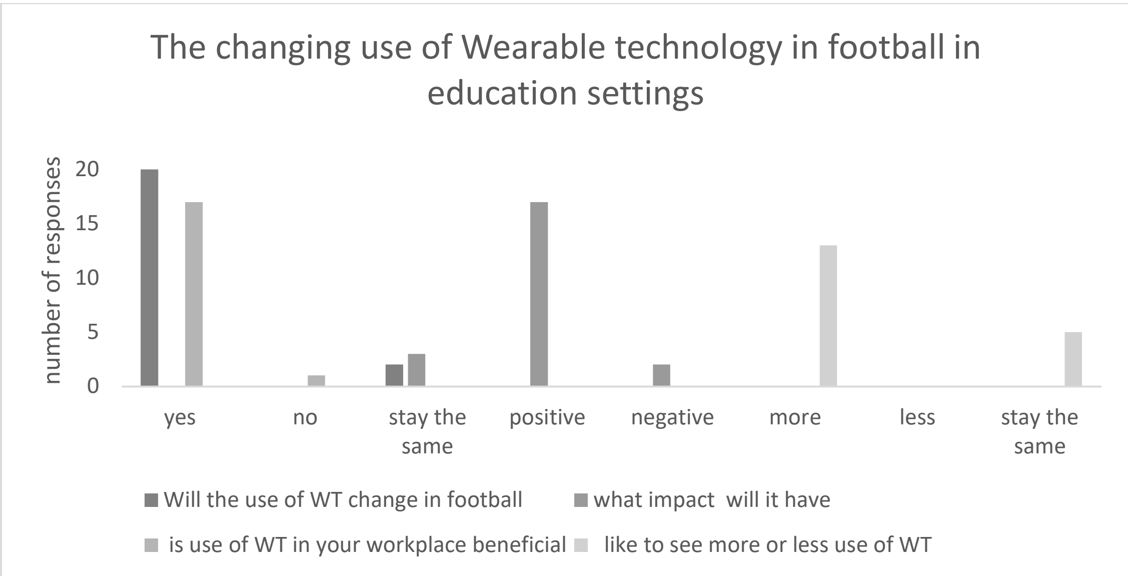
To extremely useful highlighting

"give students better understanding of the types of technology that can interact with each other to help such as Apps as opposed to outdated paper forms".

Section c) The changing use of wearable technology in the participants setting in an football and educational context,

On the changing use of wearable technology in the participants setting in an football and educational context, 91% or responses said that the use of wearable technology has or would change in football and 77% felt this would have a positive impact based on their setting and that it is, or would be beneficial to use. With 59% wanting to see more, 23% remain the same in the use of wearable technology in their setting (Figure 20), 18% responding with not applicable (N/A) as not working in these settings, this was because working in wearable technology industry.

Figure 20. Expert opinion on the changing use of wearable technology in football related education settings



Section d) Barriers, concerns and development

Answers surrounding barriers, concerns and development of use of wearable technology in football related educational setting, responses were in the form of free text answers. These were merged to give both quantitative and qualitative results using three areas being Barriers Table 5., Concerns Table 6., and Development Table 7.

Table 5. Barriers around wearable technology use in your workplace

Area	**Barriers**	
Theme	Quantitative Number of responses	Qualitative
cost	11	• cost of equipment with number of students and continuous upgrades and licencing
Knowledge	4	• Lack of delivery on specific education courses specifically FA
understanding	4	• being able to get the students to understand the importance of and the meaning of the data Lack of understanding from staff
accessibility	4	• Restricted use as need a docking station, long turn around time, unable to access the data or process easily. • GDPR compliance and student consent
simplifying	3	• overcomplicated tech that is continually changing
Misc	2	• Lazy practices. • Wearability of equipment

Table 6. What concerns if any do you have surrounding the use of wearable technology in football

Area	**Concerns**	
Theme	Quantitative Number of responses	Qualitative
Cost	2	• cost vs reward
Knowledge	6	• Too data driven need for an holistic view. • No point collecting and reporting on data if it is not being applied correctly. • Lack of knowledge on how to apply and use the information correctly from the data produced from the technology being used.
Understanding	12	• Reliability and accuracy of the data being produced. • Lack of understanding on how to use and not in context. • Data being used as a tool to punish. • Too much reliance on the data and not considering the bigger picture of other factors involved in performance and education
Accessibility	5	• GDPR compliance and data ownership specifically if being used in sports education
Simplifying	4	• Sports brands/suppliers insisting using their technology and specific unique metrics. • Too many numbers without context
Misc	1	• Lose sight of the creativity aspect of football in coach education

Table 7. In an ideal world how would you like to see the use of wearable technology develop

Area	**Development**	
Theme	Quantitative Number of responses	Qualitative
Cost	3	• Needs to be cost effective and within ever decreasing budgets. • Cheaper technology for education would make ie easier for institutions to develop their offering to students.
Knowledge	3	• Coach education-gaining knowledge surrounding correct use. • Need to be able to gain applied knowledge as opposed to current theory only approach.
Understanding	7	• Less black box. • More understanding of how can use technology to develop education of students in other related areas such as IT/literacy.
Accessibility	7	• Organically as an extension of the need for first person evidence of skills in vocational areas as part of remote learning. • Using data generated to embed numeracy in teaching and across numerous subjects. • Able to share data across multiple platforms rather that closed manufacturer's software.
Simplifying	5	• Move from paper forms and spreadsheets to interactive individual mobile type applications. • Simplify the data to something users can understand.
Misc	6	• Needs to be more individualised and player/student centred. • Needs to be able to do more than just produce numbers/stats. • More consistency and openness from manufacturers.

The largest number of responses for barriers was cost n=11, however, when it came to concerns cost only received n= 2 responses and the largest responses on concerns was understanding n= 12. In terms of development the largest number of responses was understanding n=7 and accessibility n=7.

5.6 One - One interviews.

5.6.1 Section a) Background and setting

The One - One interviews expanded on responses provided in the questionnaires, and this was useful as it helped to reinforce the selection process, was robust and gave further insight into the participants role (Figure 17), knowledge and experience. Examples of how some of the roles were more than just one specific role such as an lecturer, there were ones titled "*Digital innovations specialist", "Course leader for sport courses", "Football academy director", "Curriculum lead", "External FE and HE course verifier"* and *"Foundation degree lead"*. This was further explored with interviewees giving some history on their journey to date; this was valuable in that it helped to understand more about their experience and further reinforced their suitability for participating in the study. Interviewees responses some examples being "*I've come through a more traditional academic route undergraduate, masters, PhD and then into lecturing and module lead for undergraduate and postgraduate course at the university"*. To the other side where perhaps an more football industry route *"I was a scholar myself having played football, got injured so went into Physical Education (PE) became head of PE then worked in professional football education to now being head of Education in the Premier League, this spanning over 20 years"*.

In terms of the types of setting, expanding on those answers given in the previous study, the type of setting specifically around FE, were an FE college of Technology that was more a specialist college of technology than sport. A university center, which is seen as a transitional setting offering foundation and undergraduate degree courses at a more local level, and also used as an alternative between regional college and a more traditional university offering undergraduate courses. Traditional large city based HE University and FE College, to remote ITP colleges and football-based academies offering a blended learning environment. This provided the study with a wealth of experience and knowledge being tapped into as well as an extensive coverage of the landscape and not just geographical location, this would also involve different demographics of students (Reay, Crozier and Clayton, 2010).

5.6.2 Section b) Usefulness of wearable technology in identified categories

Interview responses on usefulness of wearable technology in identified categories, the first six questions (A-F) were more football focused and the remaining six questions more education focused (G-L) ((appendix 12.). The interviews provided deeper insight into its uses in football not only current but potential future uses and an additional emerging theme was that surrounding its use for coach education, highlighting that

"*Do coaches understand it, does it impact coaches' practices? Possibly not, because they don't have the understanding" "I don't believe the coaches are actually provided the knowledge to actually understand how to utilise GPS data and apply it in their own practice, and I think it's kind of one of those things at the minute that coaches do their FA qualifications, they get a toolbox of knowledge and drills and activities etc., but the actual day-to-day working in a high-level environment, where you're providing thing like GPS reports and things like that, there's no aspect of those courses that actually provides them that information, and I think coaches are kind of put in a situation there where they have to start working in a football environment and work with practitioners that are sports scientists that actually have the knowledge, or should and the coaches naturally just don't know how to apply that to tactics". " I just think it's one of those things that, I think if you probably asked coaches, the coaches I know definitely wouldn't know how GPS affects their tactical knowledge or how they would apply tactics etc to the game. That's pretty common". "you get to see who's not working so well, which will therefore help the team selections".*

5.6.3 Section c) Changing use of wearable technology in participants setting

The changing use of wearable technology in the participants setting in an football and educational context. In football context responses highlighted,

"*I don't think football can exist now without it, without wearable technology. We've gone past the point of no return, in terms of, I mean, even lower league clubs are putting heavy emphasis on it, and analysis of data and everything else, and that's the way the game's gone, and I think if you're going to do it, you've got to do it properly and you've got to educate help them to get the connection"* and "*I don't think there'll be a sporting environment that does not include some form of technology in that kind of aspect".*

Thus demonstrating views on how wearable technology is expanding in use in sport specifically football. With perhaps, a warning that there is a need to educate surrounding its use more in the sport of football. One example of this lack of understanding around its use being,

"make them run harder in training, and it could be a reflection on that as well, if they're not working well in training, they come in and they do education instead".

This could be viewed as being used as a tool to punish rather than educate or again further evidence of its use as a performance tool (Jones, 2019a).

In an educational context responses highlighted that where it is used that

"using that data to compare themselves to normative data and major athletes, we can get the statistics of that, so they can see where they're going again, and again, you see that kind of motivational tool using education", "they're using numeracy in a practical sense that they are passionate about, being sport-led or football-led", "improve their numeracy, to improve their understanding of data, to improve their ability to collect data, to present data, so the cross-usage there and the transferable skills".

What these responses also highlighted were that the data collected from using wearable technology, was usually a long delay before students would use, sometimes being weeks and even months, thus diminishing the relatable value of the data to the students

"*I think it needs to be available and easy to use for them", " it needs, like I say, they can access the data, and it's user-friendly, so they understand what they're looking at, it's not just numbers and stats from months ago" "you put a page of numbers in front of them, they'll just shut off and they'll go blank".*

5.6.4 Section d) Barriers and concerns

Some of these responses for barriers and concerns tended to merge, a good example being from response who highlighted

"*staff turnover, I suppose, teachers sort of come and go, and there was no momentum to build up a relationship and to start using different innovative approaches, and the way to work is, build relationships with people and then start to collaborate with interesting ideas. So the fundamental core skills, how to deliver the units, understand the systems, that needs to be in place before you start to add all the interesting aspects on top, the more creative side of it. So that stopped momentum for a year".*

And so the cycle then just keeps repeating, this was also reflected in other interviews across all the FE settings. Therefore, this section has been split into two, barriers and concerns, and development

Barriers and Concerns

Expanding on the themes in Table 2. Barriers, the largest number of responses highlighted cost as being one of the biggest barriers. This was supported in the interviews with interviewees explaining that *"the smallest number we'll ever run anything on, certainly for undergrads, is about 20, 25 students, which is a lot of units to try and convince somebody in management to buy when they go, ("Well, actually, we're not using it for performance. You're not suddenly going to win the League with doing this"), but we're going to be getting students to experience that aspect".*

However, in the interviews, cost was not seen as large a barrier or concern as other aspects such as knowledge, understanding, which received the highest number of responses surrounding concerns as illustrated in Table 3 and communication, examples of these being

"they need to gain knowledge surrounding its use and not just for playing but the many other aspects of uses" "without communication skills, what is a coach? I mean, if they can't impart that knowledge onto another, they're not coaching. So that's the way I see it, so if we're collecting data, and that data is being used for performance, if you can't communicate that in a positive and productive manner to that player, there's no point collecting it in the first place". "I would say certainly there's room for improvement in terms of cross-department sharing of information, and certainly the way we work has got to change now with the new SEP. Sport science do their thing and education do there's and so on".

The technology being used presented barriers,

"*if there was less black box thinking, we could compare manufacturers a lot easier about there being that sort of commercially sensitive algorithm or whatever's going on, which then, in terms of looking at the more holistic approach, if you can compare more readily different manufacturers, then we can actually start to get bigger databases and stuff to see".*

"*Marketing claims an example being metabolic load that some report yet has nothing to do with metabolism causing misuse of language and thus the student becomes confused and then doesn't learn anything"*

Linked to understanding is the reliability and accuracy of the many different types of wearable technology, with the following explanation provided in an interview.

"S*omeone's had an ECG. Here's the Polars trace and here's the Fitbit trace", and the Fitbit might come out with like twenty beats lower or something like that, and again, the same goes with the calorie expenditure side of it as well, which probably has less relevance to sport, but from a recreational purpose, quite a lot of people see exercise purely for the calorie expenditure, and you can sort of see that it might vary by 10, 20%, which obviously has the implications then for people creating calorie deficits and trying to lose weight, or even maintain weight".*

Again, this further highlights examples of confusing and conflicting language and data, from the many different types of wearable technology and what they report on and how this is presented, with one expert commenting,

"I probably mentioned it quite a lot of times, the application and understanding of actually the feedback that is being provided is critical".

5.6.5 Section d) Development

In terms of development, expanding on the themes in Table 7. Understanding again was one of the most responses received and linking into knowledge interviewees responded *"if a student's coming out of FE or their coming out of university and doesn't know about wearable technology and how to use it, access it, what's it about, then they're already at a disadvantage because we are in a technological world now, this is the age of technology, and if the graduates don't know how to use it, they're already at a disadvantage in the job market as well because if they want to be in the sport industry, they'll need to know what it is, how to use it and where to find it". "I don't think the way that we teach the GPS at the minute is understandable from a coach's perspective, so then a physiotherapist might use it, and I think that's the way I'd like to see it* *being used more is that there's a greater understanding from probably different roles that can interpret the information".*

Accessibility, "*if it becomes personalised, bespoke, tied to their career aims, the learning becomes joyous", "ideally is students to be able to access the equipment and the software by logging into a website or using an app or using an iPad or something like that. The issue that we have is, with the Catapult, we have it on one main laptop, which is where they have to download data, so it's quite difficult for a group of twenty students to be able to all have access to it",* Again, this very much linked to understanding surrounding the use of wearable technology. Furthermore, specifically in other curriculum areas was highlighted further with responses *"but how do then coaches utilise it, how do sports scientists utilise it, how can a physiotherapist use it? Because I think at the minute, that's what we don't have. We teach it in isolation. We teach them the theory,"*

and in more detail in specific subjects such as Math and English

"beating your personal best, you know, and that's something that is coming back into vogue, I've noticed, in particular English and maths re-sit students. By making it about ipsative, beating your personal best (PB), we're seeing incredible gains in our students, and I deal with data analysis and using biometrics to beat one's personal best rather than jockeying for position in the class or their district. I think that is so much more rich, and that move towards personalised learning, regardless of the subject, is ultimately the long-term aim for what I want to be doing. People beating their PB, going up against themselves and just trying to get better, and you can see it in professional sports, particularly in the lockdown and the way people are training".

This cross-pollination of use to other curriculum areas specifically those highlighted could bring together the teaching and learning (McFarlane, 2019) to an more holistic approach rather than the silo type culture that exists (Peters and Romero, 2019). If accessible and useable along with understanding the student journey becomes both formal and informal bringing together an array of subjects that the student can relate to and is centred around their interests.

In the value of wearable technology in football and career progression, a recent study by Hall and colleagues (2019) focus was investigating the employability prospects of sports coaching degree graduates and concluded that practice based learning in the field along with improved modes of communication and developed interpersonal skills were key requirements that increased employability prospects (Hall, Cowan and Vickery, 2019). This was further supported in an recent review (Cushion and Townsend, 2019) that highlighted whilst the use of technology has increased in football coaching, the pedagogy of coach development in relation to technology and learning was at best weak. This current study supports the findings in the aforementioned review of the literature. In addition, more recently (Bartlett and Drust, 2020) identified that communication is fundamental in delivery of sport science in professional sport and that being equipped with knowledge to translate data to an ever-growing number of stakeholders is central to a sport scientists development.

With education changing and the increased use on various types of technology, added to this the imposed changes from COVID–19 has resulted in modes of communication being increasingly reliant on mobile technology, none more so than the Mobile smart phones (Lim, 2020). As highlighted by some of the experts responses

"using an independent digital study session allowing for use of mobile phone we forget the mobile phone and to not use it is to waste the biggest resource in the history of education".

What we have seen here in this study is the disjoint between coaching performance and coaching education uses and this extends further into the other curriculum subjects. For students to graduate from FE and either advance to HE or direct employment, there needs to be an increased body of knowledge surrounding the uses and the capabilities of wearable technology used in football related FE settings. Moreover, that is not limited to just the sport department, but across the curriculum. That increases the attainment levels academically (Peake, 2018) and equally the vocational related experience (Hobley, 2016).

5.7 Conclusions

At the time of writing, the UK like many parts of the world have only just emerged from one nationwide lockdown, only to go back into another. With many educational as well as sports industries seeking new ways of working, as previously reported the engagement with technology specifically wearable technology has seen an exponential rise in its inclusion and expansion of use in both of these. Given these monumental changes, the impact of the expansion of use across education far outweighs any risks.

More and more are now supporting the use of innovations such as these, as well as the tidal wave of increased use and reliance of, in an ever-changing sporting and educational landscape. In FE settings, that provide vocational opportunity, need to embrace these new workings and be training people to use skills (Turick, Bopp and Swim, 2019). As educators, to not provide relevant opportunity and resources is a dereliction of duty, because students are going to be going into apprenticeships, jobs and university courses where they are going to be using advancing, further developing wearable technology. Therefore, it is fundamental that we prepare students and adapt either the modules and units offered and delivered or create better tools that enables them to become more independent learners, that will allow them to advance and achieve success in their careers. By embracing, the use of wearable technology in sport and education and cross-pollinating to other areas of the curriculum, will make the teaching and learning journey far smoother and more efficient than before. In addition, this could increase student engagement as well as create more independent learners that go beyond the confines of the classroom, as it becomes more relevant to them and something they enjoy.

CHAPTER 6.

Research Study 3 “Think”

The design and development of a wearable technology product for use in sport education in FE settings in the UK

6.1 Research orientation

Following the "Look" stage (i.e. studies one and two) that helped to identify the extent, type, and approach to use of wearable technology in football related further and higher education and the type of settings it was apparent that the development of a wearable technology product was feasible and justified. These empirical findings supported by my own anecdotal observations as an applied sport and exercise scientist. For instance, over the course of my career as an applied practitioner, I frequently used various types of emerging and evolving wearable technology. Anecdotal experiences of my time working in an elite performance domain(s) led me to believe that whilst the technology has advanced, our knowledge and understanding beyond the use of it just for performance are limited. These suppositions were supported by the evidence captured in both studies one and two. Furthermore, a critical review of the literature indicates when wearable technology is being used; predominantly it is for performance purposes, as opposed to educational purposes and it remain within the confines of sports performance orientated settings. Whilst it is acknowledged that in the real world of say a professional football club that is the purpose of the technology, within an FE setting, for use with students it focuses should be more on the educational aspects of the technology. Additionally, that it has potential for uses in other curriculum areas, therefore much underused where it is being used.

6.2 Introduction

In evaluating the expansion of use of wearable technology to enable it to be employed as an educational tool that can be individualised as well as for a team, there are some points to address. Constraints, such as restrictive closed software supplied by commercial companies and lack of transparency (Kim and Chiu, 2019) surrounding the technology and data produced has led many now to question. A good example being the many metrics and complex algorithm developed to interpret data produced from the various sensors (Malone et al., 2017; Luczak et al., 2019; Malone et al., 2019). To overcome this, like many sport scientists, I have adopted my own method of harvesting and using the data collected from the various commercial systems in the market and like these many other practitioners, have found it conflicting and in many cases unusable from system to system and job to job. For instance, MS Excel is an easily accessible tool with an estimated over 1.2 billion users worldwide (Park and Ryoo, 2013), that I have used and encountered in my career, but have evidenced where used in my work, in an earlier publication (Tierney et al., 2016). In addition, there is vast evidence of MS Excel being used extensively across FE and HE across the curriculum (Rubin and Abrams, 2015; Chaamwe and Shumba, 2016) and sport (O'Donoghue and Holmes, 2014; Wundersitz et al., 2015a; Wundersitz et al., 2015b). Therefore, for this research to be valid then there needs to be a fully open and transparent approach with the technology being used. As such, this particular study will showcase the process and stages required to develop a technology product for applied use within the FE industry. A product that will be more intuitive and informative and allow for levels of 'learning' beyond just being used for capturing measures of sporting performance. Thus, creating a framework that allows wearable technology to be used successfully in FE settings, cross pollinating various areas of the curriculum and not just within a sports performance context. This further supports my primary decision to opt for the professional doctorate programme as opposed to a more traditional PhD. As a reminder the LJMU professional doctorate in sport and exercise science has three main aims, these being.

1. To create and interpret new knowledge associated with professional practice.
2. To train individuals to carry out safe and independent practice.
3. To train individuals to reflect on their practice and to use these reflections to develop strategies to optimise professional performance.

One of the aims of this portfolio of work was to design and build a wearable technology product and system for use in FE settings. Qualitative data captured in the interviews (appendix 14), and descriptive data reported in the surveys of the first two studies suggest there is a need for better communication, feedback and understanding of the use of wearable technology in applied environments. Evidence captured in this thesis thus far suggests, this constraint is due to the lack of an effective product and conceptual framework, that would allow both the sporting and education sectors to better engage wearable technology. Therefore, by designing, developing and implementing a novel product and system for use in applied educational environments, it is hoped that this will fulfil the requirements of the professional doctorate. In doing so, it is my intention to allow for enhanced student engagement, attainment and transference of skills, allowing learners to become more independent beyond the confines of the classroom, and this be the research emphasis for the remainder of this portfolio of work.

6.2.1 Start up and market research.

As detailed earlier with the review of the literature in chapter two, all students need to perform research to gain an understanding of the subject area, as well as identifying problems or questions that require answers. With collaborations such as those described earlier, then the student needs to perform research which in business is also termed market research (Sarstedt and Mooi, 2014), which helps them to grasp an understanding of current products and systems being used as well as the market place and consumer demand. In chapter four (study one) and chapter five (study two) these were highlighted through the surveys conducted, which is a tool often employed in business (Brace, 2018). The focus group and research dictated on the requirements that would fulfil the needs of this study and subsequent project outcome. As with developing any innovative new product to an existing market to ensure success a robust plan (Cooper, 2019) and in depth market research is required (Deepa and Geeta, 2021). Specifically in the technology space that witnesses such a high failure rate compared to other industries at these early start up phases that results in many businesses liquidating as high as 40% not reaching it to launching in the market place (Cooper, 2019).

My first task was to collate all my previous knowledge and experience and utilise these to give a newly formed company (Quant-CX Ltd, Warwickshire) a clear plan and direction termed a road map (appendix 15.). Creating this roadmap, enabled a snapshot, that was then put into layman terms that illustrated a commercial proposition underpinned with quantifiable science. Allowing for a multitude of stakeholders to understand what was needed, these stakeholders ranged from suppliers, designers, engineers, manufacturers and sales teams. With an added benefit, helping toward gaining investment from Government business start-up loans company (Biz Britain), innovation grants from European Union and local government start up grants. This along with personal investment gave the company working capital to finance the business plan.

Along with the financial support the newly formed company received specialist support from institution such as universities offering assistance in branding, running a business, accounting and general business governance (Nepelski and Piroli, 2018). These are all crucial factors that ensure that any new start up business has the best chance of success (Turner and Endres, 2017). In addition, adopting a lean canvas model (Link, 2016) can be most helpful as it helps identify the key focuses at each stage of growth with small, innovative business such as this (Ojasalo and Ojasalo, 2020). This assistance from universities has helped graduates to access expertise that they would not normally be able to fund and has been proven to support early start-ups and encourage more entrepreneurship (Stagars, 2015). One of these specific schemes named "University Enterprise Scheme" has become widespread in use in recent years (Mason et al., 2020) and was accessed by me (the student) in evolving the business. Examples of this, being the naming of the company and creation of a company Logo. Firstly, the name QUANT-CX

Quant: denotes that solutions must have a quantifiable and measurable outcomes and results. Life is outcome driven.

CX represents 110 in Roman numerals. 110 is the angel number that symbolizes motivation and inspiration, optimising the [C]ustomer e[X]perience.

The above explanation had to encapsulate the background and what the company was about with a personal touch so that it fitted in the industry it was in, that being sports and technology, specifically tracking and reporting on performance on activity. Having an explanation and story behind the name and company has long been associated with successful companies (Clad, 2020).

Additionally the logo can say as much about the company as any words and there does need to be a balance of what the logo is and the message portraying it, also that it has to appeal to consumers (Park et al., 2013). Therefore, the initial Q was adapted to look like a magnifying glass to signify looking at your data or performance more closely, with the red white and blue chosen, not just for striking look but signifying that this was a UK based company with products produced in the UK, or the " made in Britain" approach which has a benefit of national identity. As well as linked to producing reliable and accurate products, which is needed for the intended market (O'Shaughnessy and O'Shaughnessy, 2000). Conversely there are some that have shown that this kind of brand association can adversely affect some businesses trying to replicate similar iconic brand association and national identity such as that of the Post office (Heller, 2016). However, these were all considered and discussed with mentors and university experts and concluded that the start-up company would brand itself associating with the " made in Britain" approach and red, white and blue colours used (Figure 46), as these are associated with the approach .In addition, as it was in keeping with the company evolving philosophy of building a product by experts in an industry for the industry, with industry being sports technology, football and education and for use primarily in the UK.

The second example was in helping to build relationships and networking to improve the profile and accelerate exposure to a more diverse and wider population. In recent years social media has become more widespread in use and there are many platforms that facilitate advertising and promoting image. LinkedIn is one of these and is seen as more used for businesses and professionals to network, form and develop relationships and for marketing purposes (McCabe, 2017). With the help of a university enterprise scheme and accessing expert help enabled an effective profile for the company and Chief Operating Officer (CEO) who was also the current research student, so that these became intertwined as the business and project progressed. This has led to over 500 connections that relate to both the students research and business relations (appendix 16.) in terms of exposure and marketing a post highlighting the product and current market was composed and posted, which resulted in over 14,522 views and 82 comments with the vast majority then enquiring further (appendix 17.). The results of these enquires led to direct sales (n=650) for the company and guest lecture slots for the student at university (n=1) and further education providers (n=9) with three being FE college, two with ITPs and four at football academies. Thus, fulfilling some of the aims of the research students self-audit action plan which was to develop professional practice and improve employability prospects in these sectors. In addition, improving my understanding of appropriate research by employing an action research methodology (Coglan & Brannick, 2010). I have improved the ability to better identify, collect, collate, critically analyse, synthesise, summarise, report and disseminate information that relates to my research area and communicate these in a succinct manner to various stakeholders from industry and academia.

Following on from the setup of the business and the road map, there then needed to be conducted further research on what was being used in the market currently (Appendix 18.). As well as formal market research, the collecting of information from experienced practitioners in the field such as from the researcher and study group is an informal strategy that has been adopted in recent years by innovative start up entrepreneurial enterprises such as that being collaborated with here (Stokes, 2000). These clearly supported the key findings of study one on the barriers to use, one of these being cost (appendix 18.) both upfront and ongoing, in the form of capital and or operational costs.

These operational costs tend to be in the form of a licence type model that many in the wearable technology sector have adopted and similar to mobile phone type contracts (Coulton, 2015). Whilst popular with the industry and commercial businesses, it is problematic with many FE and HE institutions that tend to work on capital expenditure projects as opposed to operational expenditure (Kholmuminov and Wright, 2017). A lot of this is due to how these institutions funding and financing are set up and operate and as previously highlighted, the technology industry specifically the wearable technology sector has been growing at an exponential rate with new products being released and upgrades to existing ones. Therefore it could be argued that the operational expenditure approach could be a more beneficial option for institutions and in line with the wider society (Danasekaran and Raja, 2019), unfortunately there are many that are resistant to this as this involves changing views and methods of work (Nayar and Kumar, 2018). This is an important factor to keep in mind when developing products for any market in understanding the many factors both direct and indirect that are involved. A better approach would be to educate through highlighting the benefits to changing to a new operating system and process such as described here. Financially, illustrating the immediate savings as well as future savings would be an added benefit especially in the current climate with changes to funding from government as well as new practices being sought to combat the restrictions of COVID-19. By collaborating with institutions and employing students further demonstrates other additional benefits that should be also included in the bigger picture.

As part of the market research the AOC hold regional meetings for FE college heads of sport and curriculum leads. I was fortunate to be allowed to present my research plan (appendix 4.) as well as conduct questionnaires and group discussion on use of wearable technology in their various FE settings (appendix 8.), the feedback from these was inputted into the previous study as well as contributing background information to the focus group. This approach also had added benefits, it helped to publicise and promote the research to a wider audience that was specific to the area of research as being FE sector and increased the network of contacts that the researcher could draw from as and when need arise. From a business perspective these were all of benefit as they helped to increase the exposure of the company to much wider audiences, a good example being Coventry University Enterprises (CUE) promoting support of an Alumni and local technology start up business (appendix 19.).

6.3 Determining product components.

With any product there has to be first a proof of concept stage (Swanson et al., 2003), this includes variations of similar types of products that are already in the market place (Salazar-Cabrera, Pachón de la Cruz and Madrid Molina, 2019). The brief for the concept was from business commercial standpoint, sports industry specifications and requirements, the research project and summarised by me the research student, being the CEO of the company and overall project leader as follows:

"To create a system that was affordable to more people than before, was similar to other products in the marketplace yet had unique features that filled a void that existed for accessibility, individualised, adaptable and simplifying to wider audience including those in further education".

At this stage, myself and two of the focus group were able to draw from previous experience and published research, which we developed an mobile application for use in football and compared it to a range of GPS tracking type devices employed in the football industry (Tierney and Clarke, 2019). This went further as we trialled the concept as part of my supervised experience for BASES, in walking football, a leisure and exercise programme developed for use in the wider community to increase exercise and engagement with others (appendix 20.). This was a mix of being a performance tool as participants could view their performance over time and compare against others and for educational purposes highlighting that by increasing activity had the added benefit of improving general health and wellbeing (Krustrup and Krustrup, 2018). This was also presented to commercial enterprises that specialise in football activity by conducting trial within their existing client base (appendix 21, 22.) by doing these highlighted the wider use outside of use in professional elite football. These commercial enterprises were investigating opportunities for increased uptake as well as improving their appeal to wider and more diverse populations, a key requirement to continued success in business (Ngo and O'cass, 2013).

On reflection, as to the importance of performing this, as well as for opportunity for a potential commercial customer, there was also evaluating the use in leisure type activity as described here. As detailed in the earlier review of the literature, a vast majority that participate in football do so outside of the professional game. This includes students as part of the wider society, therefore this could be included as a component of independent and a more informal learning that could increase attainment in core curriculum areas such as Numeracy, Information Technology and Language. This would have the added benefit that it would be recorded thus providing quantitative data which is lacking in evidencing informal learning within education (Rizk and Rodriguez, 2021). Increased engagement in semi structured activity such as this and being able to quantify the learning experience not only evidences increased learning opportunities it also helps students better relate to their learning (Rogers, 2014; Jin, Kim and Baumgartner, 2019).

Following these, further meetings were held with the focus group and key stakeholders which now included Software engineers and developers, hardware engineers and mobile app developers. This was because the focus group had identified three key factors to enable the project to progress, these being

Device – this would be the hardware, the electronics that would be worn by a participant to gather data

Housing – how the device is worn whilst gathering information this being an enclosure for the electronics, usually made of a plastic material and a garment to accommodate the device

Communication – this being a method to transfer data from device being worn by participants to a visual interface displaying the experience of what the device recorded.

All of these had to be evaluated as well as meet the needs for the project, as described earlier. The project had two parallel tracks, these being the research, for the researcher to fulfil the professional doctorate in creating the aforementioned project and secondly the business and commercial viability of an innovative product. A series of meetings with all stakeholders concluded that the two parallel tracks and all three elements identified could run concurrently, as each was reliant on each other to progress through the stages of development. It was also recognised that whilst football is a team sport and students are generally lectured in groups. To help create more independent learning that the system created must be able to accommodate both team or group use and individuals, in such a way that they crossover and merge to be able to be used as an individual within an team or group, purely as an individual, and purely as a team or group. This would therefore require the communication element, specifically the software to be agile and adaptable to meet these requirements.

To enable effective communication between each of these identified elements and monitor progress a common tool used in business is a project management board that can be accessed online. For this project the business partners (QUANT-CX Ltd) online web-based tool was employed Trello (New York, USA), they also allowed for the researcher to combine with their doctoral study (appendix 23.). Within the professional doctorate journey a key aspect is the use of reflective practice, normally conducted as the name indicates on reflection of a practice performed to help evaluate how one is performing and how to progress. In this study the use of reflective practice will be conducted during the write up to help evidence the effectiveness of its use during practice (Hawkes and Yerrabati, 2018; Boud et al., 2020). This is because the approach being used dictates that continual reflection, evaluation and changes are made as the product and project develops. Having a number of moving components that also have a commercial impact an overview as well as the capacity to drill down into is warranted.

One of the first tasks of my professional doctorate was to produce a research plan (appendix 1.) and timeline (appendix 2.). This is very similar to the planning within this current study and the timeline similar to the aforementioned Trello board, allowing for an overview of the concurrent workings as well as displaying the fluid movement of stages of the project in the form of an overview that can be drilled down into, to view more detailed content of progress (appendix 23.). As the researcher has worked in the area for an extensive number of years, a vast network of colleagues in many related industries has formed. A good example of this is in the software, as the team and company employed to assist with this part of the development is based in India, along with electronics engineers from Poland and Latvia, and front end or insights visualiser based in Australia, made this a truly international project. This further supports the use of online management monitoring tool such as Trello. Also that in applied practice it highlights the importance of building relationships throughout ones careers, especially in doctoral research such as this (Gluck, Blumenthal and Stoto, 1987). With many of these recruited within project having additional roles such as mentoring the researcher, which has been shown to enhance a more independent learning as well as improve their future employability and increased development as a professional (Singe et al., 2021). To assist with the commercial side, a pilot study is needed to demonstrate the commercial viability of the project for the business partner (appendix 24.).

Before commencement of any work by external stakeholders such as engineers and developers, it was important that the ideas were understood by the engineering team, therefore, a series of meetings was held to determine the final design for a working prototype. Simply put, it is where an idea becomes a physical entity or a reality. The three areas will now be described separately as to the journey from idea to completion. However, before they are the first point to address is any restrictions surrounding use in sport of football. As previously mentioned in the review of the literature, under the laws of the game electronic systems such as this being developed need to conform to the sport rules, regulations and laws set down by the sport governing bodies. The global sport governing body for football or soccer as it is also known by is FIFA and has termed wearable technology under the category of electronic performance tracking systems (EPTS) (Dunn, Hart and James, 2018). Under the laws of the game of Association football, the use of wearable technology has been allowed since 2015, during competitive match play (Brud, 2017; Linke, Link and Lames, 2018). However, this technology being used must conform to the minimum safety requirement to be allowed for use. This is called the International Match Standard certification and is awarded by FIFA following rigorous testing (FIFA, 2020). This is in line with other sports such as rugby (Rugby, 2019) and electronics in general commerce that have to conform to minimum standards in industry (Commission, 2019; EU, 2020). Therefore, consideration is needed when designing and manufacturing any product for use within the scope of sport and any consumer use.

6.3.1 Device- Hardware electronics

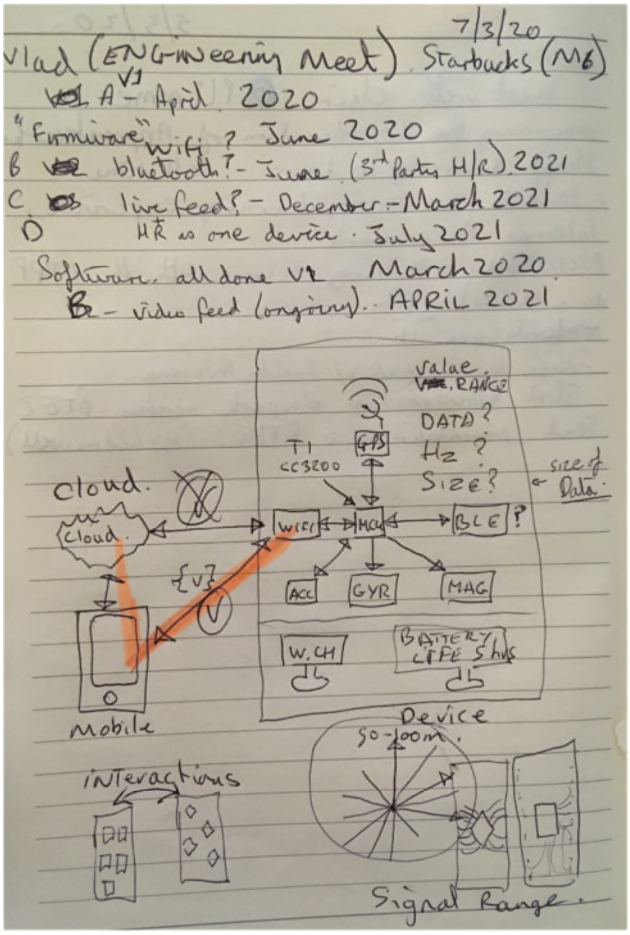
The team for this consisted of student enrolled on the professional doctorate programme at LJMU (me), who was performing the role as project manager, electronics designer, engineer and firmware or embedded software engineer. There would also involve interaction with the experts in the other areas mentioned of communication and housing.

Having previously worked with some of the engineers an understanding of basic requirements already existed, a first meeting quickly scoped out what the key elements required for the electronics part to work and how the system would work (Figure 21). This required discussion on basic minimum requirements to enable a device to function and how all the components would interact (Figure 21). This was broken down into four key elements, including Power, sensors, device management or controller and communication.

Power.

For battery management, on off function and power to Micro Controller Unit (MCU) or the brains of the device displayed in (Figure 21). As the project progressed external events caused adaptation to be made. Lithium-Ion batteries are commonly used in electronic devices such as these which are similar to those installed and used in mobile phones. Following some publicised cases highlighted by the media, where mobile phones had accidently exploded due to damage or incorrect charging, Material safety data sheets (appendix 25.) as well as restrictions in shipping these highly flammable batteries became the new norm. Whilst the costs increased, the benefit of continuing with this source of power was deemed far greater by all the experts and therefore the focus group directed, the inclusion of Lithium-ion batteries necessary.

Figure 21. Hardware design sketch, power flow, interaction, and battery management



Hardware sensors and interaction of system

Power management and Battery power flow

Redacted due to commercial sensitivity and copyright

Sensors

The components and sensors required, these being standard types used in similar such devices including GPS module, Accelerometer, Magnometer, Gyroscope. That said, it was found that with each of these sensors there are a vast array of types and having different functions (Mencarini et al., 2019). Additionally, as detailed in the review of literature that wearable technology has developed from a more consumer led than scientific perspective (Aroganam, Manivannan and Harrison, 2019b). Furthermore, it was highlighted that companies supplying wearable technology needed to be more transparent with the insights produced from devices and better educate users on the technology (Kim and Chiu, 2019). Therefore, it was important that a clear understanding of the use of the device once produced was had by all the engineering team. With football being one of the most popular sports worldwide, all of the team had some knowledge of what would be required. Furthermore, the student spent a period of the placement working with specific experts such as sensor suppliers. Alpha micros (Basingstoke,UK) is one such supplier who are the main distributors in the UK for Global navigation satellite systems manufacturer which includes GPS named UBLOX (Thalwil, switzerland). UBLOX is a brand leader with over 20 years manufacturing to the vast majority who operate in the areas involving wireless communication such as those being developed here and in sport.

A subgroup was created that included experts in the various fields to input to the project, including those from aforementioned company (Figure 22). With GPS type being the most common sensor used, there required further background on the development of, not just within the UK but globally, as this was an industry placement, the commercial viability of the project needed to be included. Therefore, an in-depth investigation to evaluate the optimal solution was sought. The referencing to the earlier literature review proved to be most valuable as the student was able to present comprehensive summary of the scientific literature surrounding the use of sensors such as those used in sport in wearable technology. This included background information conveyed to the team, an example being the types of systems and main sensors used (Duking et al., 2016; Wagner, 2018; Aroganam, Manivannan and Harrison, 2019b).

Global Positioning System

GPS was first used by the USA and closely followed by Russia with the first satellite launched in 1978 and has seen a steady growth to now over 150 GNSS satellites in use (Cao et al., 2021). The four global GNSS systems being GPS (US), GLONASS (Russia), Galileo (EU), BeiDou (China). Additionally, there are two regional systems – QZSS (Japan) and NavIC (India), with these latter two scheduled to be global in future (Gao and Enge, 2012). It has been shown that the Galileo system has a greater accuracy than the current version of the American GPS. This is because the exact location of the satellites is known, therefore the receiver can calculate its own position based on the time difference of the signals it receives from at least three satellites to an accuracy within 20cm (Li et al., 2016; Xia et al., 2019) . GLONASS is a global satellite navigation system, providing real time position and velocity determination for military and civilian users. NavIC covers only India and its surroundings and is considered to be more accurate than the American system. It has been reported that NavIC is technically superior to the American GPS, as this system has dual frequency with both S and L bands (Desai and Shah, 2020). In terms of positional accuracy GPS is slightly better than GLONASS overall, but due to the different positioning of the GLONASS satellites, GLONASS has better accuracy at high latitudes, therefore consideration is needed to determine which to be the optimal one to use (Yigit et al., 2014).

Accelerometers typically contain a piezoelectric crystal element bonded to a mass. When the accelerometer is subject to an accelerative force, the mass compresses the crystal, causing it to produce an electrical signal that is proportional to the level of force applied.

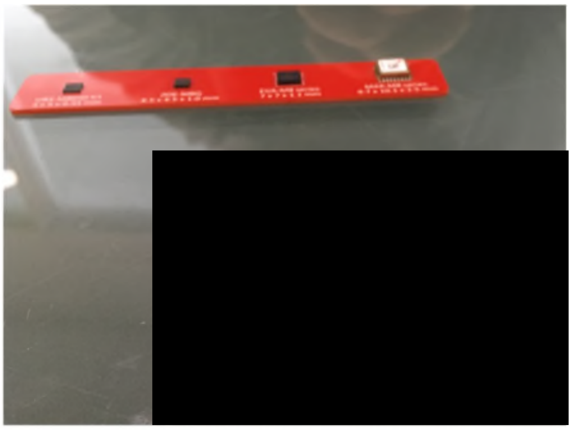
Gyroscopes, (gyros), are devices that measure or maintain rotational motion. Micro Electro Mechanical System (MEMS) gyros are small, inexpensive sensors that measure angular velocity. The units of angular velocity are measured in Degrees Per Second (°/s) or Revolutions Per Second (RPS). Magnetometers are an electronic compass that help to understand orientation in relation to magnetic north. In terms of athlete monitoring, magnetometers provide information regarding direction and orientation, helping practitioners to understand the volume of key movements such as changes of direction.

On selecting various sensors as mentioned here, by having GPS devices that incorporate other technology such as accelerometers and combine the two, have been found to be more accurate and more able to record high speed multidirectional movements that occur frequently in football than GPS alone (Barrett, 2017; Malone et al., 2019). However this is not restricted to just the sport of football as such devices created have been found to be beneficial in other related sports netball (Cormack et al., 2014), Rugby (Howe et al., 2017). These sensors once selected would then need to be evaluated on compatibility with each other as well as be able to perform as expected. This involved meeting regularly with the engineering team (Figure 22) to assess each stage and each of the sensors an example being the GPS sensor as illustrated in (Figure 22).

The sensor once selected had to be evaluated on working which involved mounting onto an prototype Printed Circuit Board (PCB) with a power supply with same voltage as that to be used in the device being developed. It also required to be able to pick up satellite signal. This was achieved by pairing with a mobile phone GPS tracking app using Google maps and Bluetooth technology (Figure 22). As part of the placement, the research student also attended conference events to gain a more comprehensive understanding of the technology world and ongoing developments (appendix 26, 27.).

Figure 22. Sensor evaluation and mobile compatibility

Engineering evaluation meetings



Sensor selection

GPS sensor evaluation

Device management and communication

A Micro Controller Unit (MCU) being a small, self-contained computer that is housed on a single integrated circuit, or microchip was used for this part of the electronic device, or could be described as the brains of an electronic device. They differ from the type of brains found in desktop computer and laptops, in many ways not just the size as they are sometimes dedicated to a single function (Liu and Wang, 2012) and are most often embedded in other devices examples being smart phones (Coughlin, 2018). On selecting this type for the project involved inputs from designers and Engineers from electronics, software, embedded software and developers to ensure that what was finally selected would be suitable (Gaillard, 2013). Fortunately, having worked in this technology space the project team were able to select one that met the needs for the project. The communication element of the electronics device are internal and external. For the internal an embedded software engineer created the programming source code to allow for the MCU to communicate with all the components and sensors within the device electronics. This software would also communicate with the MCU and individual sensor embedded software, sometimes referred to as firmware, this being a type of software that is usually embedded into components such as sensors examples being GPS and accelerometers.

Put simply this is a bespoke programme created for the device to enable all the components to work, interact and communicate with one another, record what is being done and prepare data in a format and ready to send. The external is how the device send and receive this data, again as this device needed to be similar to what being used in sport and to conform with rules and regulations this was to be done wirelessly. A USB port with an external connection is an option commonly employed in sports tracking devices, this had some marked disadvantages such as additional costs for materials as would require a cable, debris and water clogging the connection area. With this being something highlighted by users in the field, as well as in study 2, as a restriction in that it required a docking type station or computer to connect to extract the data (Figure 23) these being commonly used in football industry.

Figure 23. Commercial docking type stations commonly employed in football

.

Then there is the ever-advancing wireless technology in the form of Bluetooth and Wi-Fi enabled communication. Following evaluation and discussions with the experts and focus group Wi-Fi was selected, in explanation of this choice was as follows; Again, by drawing from previous experiences from members of the team both in electronics and in the field, it was decided that Wi-Fi would be employed over Bluetooth which is more commonly used in sport type GPS devices. However, there were some compelling arguments why Wi-Fi was chosen (Friedman, Kogan and Krivolapov, 2012; Lindemann et al., 2016). First Wi-Fi has a much faster download speed than Bluetooth over six times faster than even the latest Bluetooth 5 chipset (Li et al., 2020; Sharma, 2020), so given that our thirst for instant feedback is ever-growing is an advantage. There then is the additional feature that Wi-Fi has no restriction to the number of connections it can make at any one time (Abedi, Abari and Brecht, 2019). Therefore, for use in team sports, large group settings such as lectures, then this is another advantage. Bluetooth chips tend to be more expensive than Wi-Fi and the amount of energy used can add to the power drain of the device, this in turn would impact on the size of the battery and size of device with placement of additional Bluetooth chip. This should not be confused with the current project as Bluetooth is a lower energy drain than Wi-Fi when used separately, which is not the case here as with Wi-Fi the project had identified using mobile phones and Tablets to visualise the data at the user interface stage, there would require Internet connection to allow for interaction with analysis servers via a cloud-based system which meant Wi-Fi connectivity enabled device would be required. Thus, if Bluetooth were also selected this would mean that two components instead of one would be used, causing additional space, cost and power. This again is where a commercial cost benefit has borne out of a functionality selective process.

The embedded software engineer created the programming code to allow for the MCU to communicate with all the components and sensors within the device electronics (Mahmood et al., 2020). This software would also communicate with the MCU and sensor "firmware", this firmware being a type of software that is usually embedded into components (Rahman, Daud and Mohamad, 2016; Kvarda et al., 2017).

There needed to be consideration for noise and interference not only in the design stage, that required the GPS sensor to be placed such to maximise the signal, also that a clearance also termed "ground plane" (Castillo et al., 2009) was required surrounding the sensor to minimise any interference from external forces such as other electronics including sensors within the device (Markgraf, 2019). In addition, the logging and interpretation of data produced by the devices.

Algorithms created to combat this are commonly employed in electronics, the most common being Kalman filters. Previously reviewed as part of the literature review the engineering team created their algorithms using an a Cascaded Kalman filter as this has been found better for tracking human movement (Zihajehzadeh et al., 2015), than other types such as an Extended Kalman filter (Hashlamon, 2020). Commercial sensitivity and Non-disclosure agreements (appendix 14.) prevent publication of the specific construct of the algorithm created. This does highlight the research student contribution, as having performed a review of the literature on wearable technology, specifically surrounding the use of types of technology (Aroganam, Manivannan and Harrison, 2019b), helped to inform better the decision making process in the industry setting. Furthermore, as described on selecting the type of GPS sensor found that in addition to these improved algorithms being employed , that sensors that provided a higher sampling frequency or ones that could be interchangeable were far more accurate recording movements replicant to those found in sport such as football (Malone et al., 2017; Murray and Varley, 2019; Zago et al., 2019).

Another consideration is that of GPS drift, 1.5 meters average in the most practical sense, is the difference between your actual location and the location recorded by a GPS receiver. The earth is round, and satellites are orbiting at an exceptional speed in excess of 11,000 K/mhr. A GPS type device uses data from satellites to locate a specific point on the earth in a process called trilateration. This is different to triangulation and is commonly used to measure distances in electronic measuring devices such as those being used in sport (Pricone and Caracaş, 2014). To trilaterate, a GPS receiver measures the distances to satellites using radio signals. Three satellites are required for triangulation of a signal to give approximate location. However, the GPS receiver needs four satellites to work out your position in 3-dimensions termed trilateration. If only three satellites are available this is triangulation, the GPS receiver can get an approximate position by making the assumption that you are at mean sea level. As described earlier in the review of the literature, the need for an understanding of the types of devices and sensors is crucial specifically for different uses. Moreover, in sport those that report on finite fast movements such as those in football, require tools that are able to measure with accuracy. As to the importance of the types of algorithms employed in computation must relate to the purpose of what being used for (Zihajehzadeh et al., 2015), as was reported in the literature review within this thesis.

Once these stages were completed the electronics engineers proceeded to construct detailed designs of the electronics referred to as the schematics (Figure 24) ((Race et al., 2019) and also mock up drawings using Computer Aided Design (CAD) engineering software to create visual 3dimensional views (Robertson and Radcliffe, 2009). Once the engineers were happy the first prototypes could then be produced.

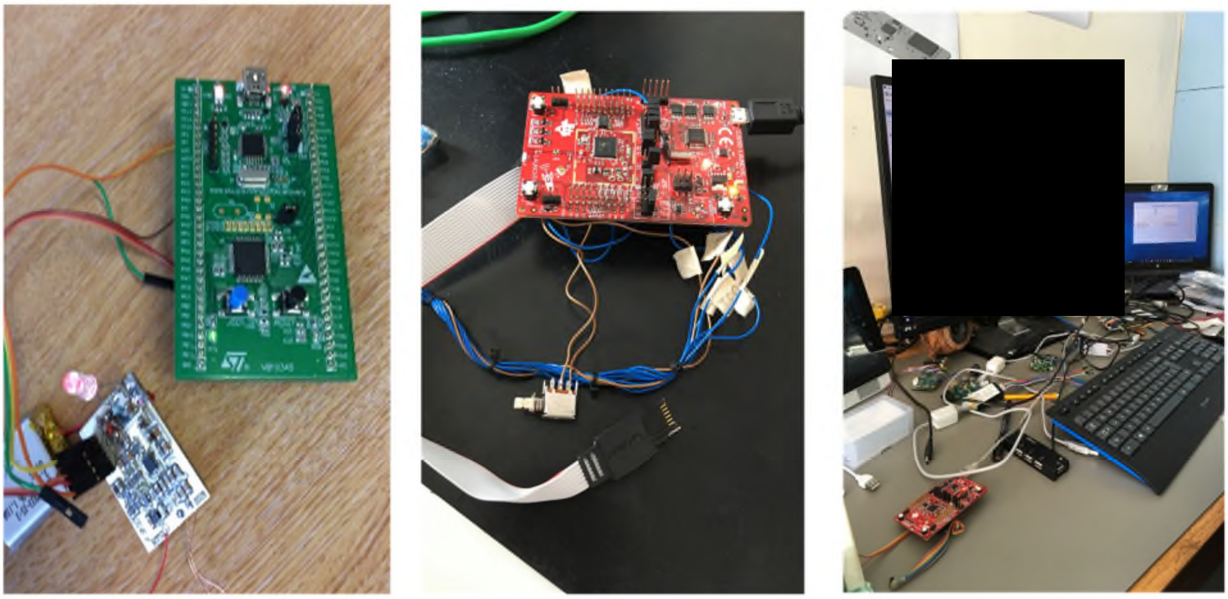
Figure 24. Schematics and CAD of proposed electronic device

[redacted]

***Redacted due to commercial sensitivity and copyright**

This involved three iterations of building a prototype device with the first being an evaluation board or version (V) 1, version referring to each iteration as the device progresses towards the finished product that can be evaluated in the field and once final sign off approved can then move to full production. The V1 was much larger and not the shape than the final version would be, this was because the ideas that were earlier created and formulised, were now being produced for evaluation and these may need changes that were unforeseen. This is sometimes referred to as "proof of concept" stage so building a conceptual prototype (Figure 25). This early prototype built using off-the-shelf components with little to no custom hardware design. Additionally, engineers using development kits and boards that are available from chip manufacturers within the electronics industry (Hartman, 2014) as these vastly reduces the cost at this stage of development. There is also the added benefit that these are readily available therefore reducing the time to construct and evaluate this stage.

Figure 25.. V1 Prototype and programming board including circuit flow testing



V1 prototype board V1 programming board V1 circuit flow

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Once this stage was completed and the engineers had confirmed all the components they then continued with the prototyping process, the next stage being to design and build an PCB and populating with the components and sensors from earlier. Whilst it is beyond the scope of this current study to detail every component, selection and each iteration, of the phases involved, it is important to provide a summary of these phases to understand the overall scaling of the project from the initial concept to final production of a product (Armstrong, 1999; Shina, 2012; Khurana and Hodges, 2020).

V2 involved the building of PCBs and then populating these with the components including the sensors (Figure 22), and then testing of the functionality of, an example being GPS signal. For this not only was the hardware but also the embedded software was required (Figure 26), to enable the evaluation of how a finished device would function and that the sensors performed as expected. This would also involve the software being developed that an end user would be able to view the data as insights into what they had done.

Figure 26. V2 & V3 prototype electronics development and assembly

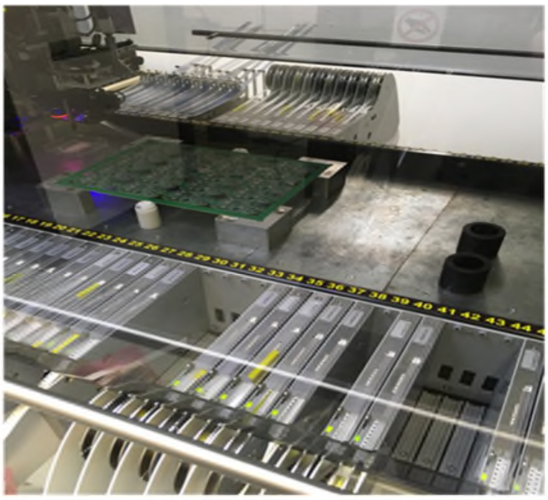
[redacted]

Redacted due to commercial sensitivity and copyright

The V3 phase, moved away from the manual process of building the devices and involved using pick and place machines this ensures that each device is an exact replica of each other as the components are more precisely placed (Chalsen, 1991), as the components are placed onto the PCB by a machine (Figure 27). Automating the process which is the final process when the devices are being produced at the production phase (appendix 28.). This process is nothing new in the world of electronics as being an increasingly common used method for over 20 years (Magazine and Polak, 1998). With the V3 phase now completed, the enclosure could now be finalised and allow for field testing to be performed in order to further evaluate the function of the device, garments, housing and communication.

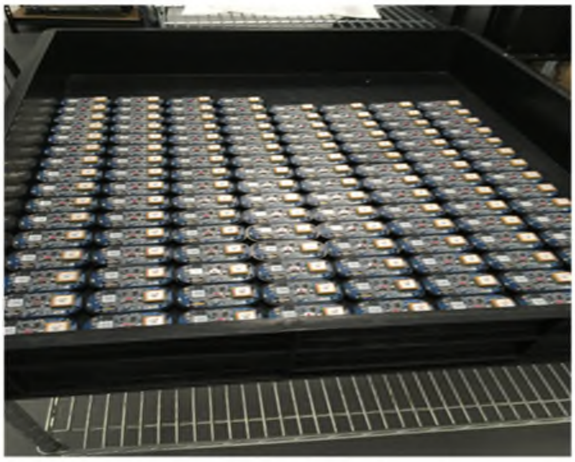
Figure 27. Automated build and assembly of electronics

Production line pick and place machines



PCBs being populated along automated production line

Enclosures with battery and charge coils for final assembly



Completed electronics ready for final assembly

6.3.2 Housing

There were two elements to the housing, first the enclosure for the electronics and secondly a garment to enable a user to wear the electronic device unrestricted and conform to the sport requirements to allow for use.

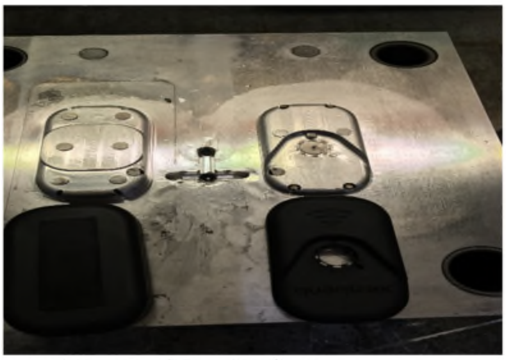
6.3.2.1. Enclosure

With any new product that is built in a specific way to set parameters, to perform what is being produced for, will inevitably be different to anything else, therefore, it cannot easily be housed in an off the shelf enclosure. An example of this being the following;

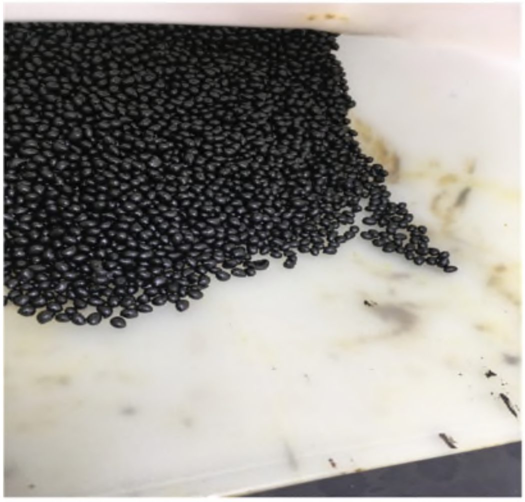
imagine when going away for a weekend break flying abroad, you will always pack differently to the next person and most likely have a different size case or bag to place everything in. Before being allowed to board a plane with hand luggage that is to be stored above seats in overhead lockers or under seats on the plane, the bag first has to be checked that it conform to certain dimensions to be allowed on board, these are set requirements dictated by the airline travelling with. There is then the look and feel as you want it to look aesthetically pleasing to the eye yet has to be practical for its purpose as here it would require a handle of some sort, a method to open and close, be strong enough to withstand external factors such as weather and impacts from movement, It is a similar set of principles here. The enclosure must be able to house the components whilst being able to function and be aesthetically pleasing to the eye and conform to industry requirement for where it is going to be used, as in this case in football and similar types of activity.

The electronics factory where the student placement was situated had experience of working with manufacturers of enclosures as part of their supply chain. Their knowledge and previous experience being employed to help formulate the optimal approach to a solution. The type of enclosures used in this area of wearable technology are commonly constructed of plastic or polymer materials and produced using what is termed injection moulding technique, which is a fast process that can produce large quantities that are exactly the same. The process involves material granules, fed via a hopper into a heated barrel, melted using heater bands and the frictional action of a reciprocating screw barrel. The material is then injected through a nozzle into a mould cavity where it cools and hardens to the configuration of the cavity. The mould tool is mounted on a moveable platen and when the part has solidified, the platen opens and the part is ejected out using ejector pins (Figure 28).

Figure 28. Injection moulding prototype and production tooling



injection moulding tooling



Material prior to heating and moulding

prototype moulding and heating

However, injection moulding is an expensive process and one that many SMEs especially those like this one that are developing a product that may require future iteration that would subsequently change the dimensions of the enclosure required, are unable to finance. Given that injection moulding tooling can cost upwards of £25,000 Great British Pound (GBP) for products like this, with any future changes then requiring further adaptations to the steel tooling being used by a toolmaker, which is a very highly skilled profession and as such demands premium price. Therefore, the cost benefit is one that has to be considered.

As with all innovation and evolving technology enclosure manufacturing process are also continually adapting. One such process that the electronics manufacturers have adopted in recent years is that of over moulding. This is a similar process to injection moulding but one where the electronics sits within a mould and then heated material is poured over to encase the electronics within the cooled material. This is a low-cost manufacturing process and offers potential benefits such as, reduction in processing time, higher freedom of design and changes to when compared to the aforementioned conventional injection moulding method and at a fraction of the cost being up to 90% cheaper. This is not without dangers, as there is a risk of damage to components and reduced functionality. Therefore, in addition to researching the literature surrounding this method (Huttunen et al., 2018; Bakr et al., 2019; Kololuoma et al., 2019; Ott and Drummer, 2021), a test of this process would be required. There were concerns raised by the research student following the review of the literature surrounding the use of this over moulding process these being

1. The material being used to encase the electronics could potentially damage the integrity or functionality of the components.
2. The battery being rechargeable wirelessly, therefore the thickness and density of material being used must allow for function of recharging as well as not damage the integrity of the type of battery being used being lithium ion polymer type
3. That the aperture for the on off function namely the button was uninhibited and that there were no sharp edges
4. That the material being used and completed product, would conform to the sport industry requirements.

As the electronics company had performed similar projects previously, these were noted, considered and incorporated to the specifications relayed to the over moulders, with the main changes being that a resin material would be used (Burk, 2001) and thickness of material decreased (Webb et al., 2006). The results of the over moulding process were not as envisaged. They did highlight that the points raised were valid (Figure 29). That for the wireless charging of the battery would require a different material or process or both. Thus evidencing the value of reviewing relevant and associated literature that is unbiased (Oliveira, Cohnstaedt and Cernicchiaro, 2021).

Figure 29. Over moulding tool and finished prototype

Overmould tooling

front and rear view of encased electronics

Front side with button and reverse side with battery charging coil visible finished prototype overmould

There were also two further observations. The GPS module was unable to connect to any satellites due to the density and thickness of the material used. It was clearly evident that the aesthetics were not replicate of a product that could be launched into the consumer market (Figure 29). Even with this at a prototype stage and not a fully finished consumer ready product it was clear that this was not in keeping with similar products already in the marketplace.

In consideration of these points and results, there required a series of meetings involving the focus group, the company employing the manufacturers and financing the project and the project team. A rescheduling as well as re-financing of the project was formulated (appendix 29.) to allow for exploring the more expensive yet conventional injection moulding process.

This would involve a 6-step process.

Step 1. Design including mock-up drawings.

The design of the enclosure had to be such that it was aesthetically pleasing whilst being able to function and conform to the industry requirements. From the previous experiences with the over mould process, the type of material and thickness (Teh et al., 2000) as well as the added inclusion of the ground plane as previously mentioned were all points to be considered to ensure that the end product met all the requirements. A product design consultant that specialises in this area were employed 3DI (Northampton, UK) to produce mock up drawings (Figure 30).

Figure 30. Design mock up drawings for electronics device enclosure

Step 2. Sign off of final design and prototype enclosure

Once a design was selected a 3D printed prototype was produced to allow for testing of fit, functionality, look and feel with the electronics fitted within the prototype enclosure (Figure 31).

Figure 31. 3D printed prototype enclosure for electronic device

3D printed prototype enclosures

Prototype enclosure with electronics

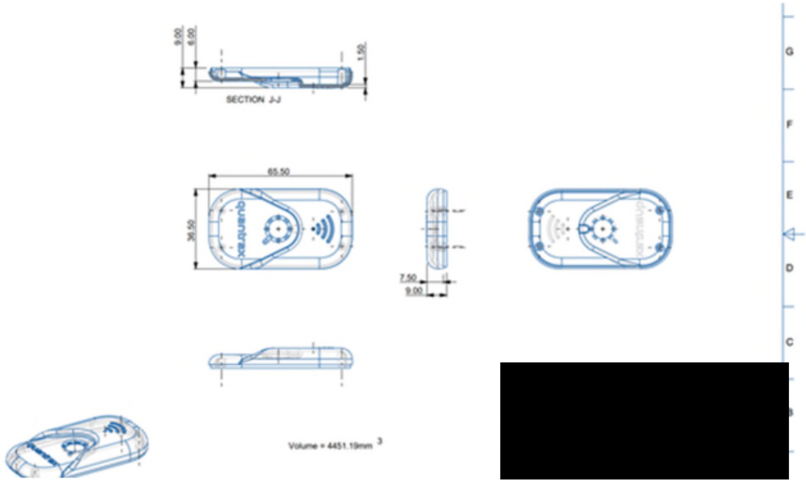
3D printing has become increasingly popular method to produce prototype products (Candi and Beltagui, 2019), with many manufacturers adopting its use at all stages of a manufacturing process (Schniederjans, 2017). More specifically, at these early stages with developing an innovative electronic device as here in this current project (Lee et al., 2017), with additional benefits of being relatively cheap and readily available. A selection of designs and subsequent 3D printed enclosures were produced and following in house testing to ensure all requirements were met, the final prototype enclosure was approved and signed off as complete (Figure 32).

Figure 32. images of final prototype enclosure

Step 3. Tooling

At this stage the team involved was expanded further, in addition to the designer there now required the services of a toolmaker and injection moulding manufacturer. Similar to the snowballing technique used in study two, the company was recommended by the 3DI designers, the company selected Plastic Parts Direct Ltd (Banbury UK) was one that had experience of producing similar products for the motor industry using injection moulding and added benefit of their own in-house toolmaker. In addition to the designs and prototype 3D printed enclosures, a specific type of drawing was required to enable the toolmaker and injection moulding company to precisely build a tool to enable enclosure to be produced (Figure 33).

Figure 33. CAD drawing for toolmaker specifications requirements



***Redacted due to commercial sensitivity and copyright**

It is interesting to note that whilst this project involves the production of an innovative product in wearable technology and using advanced technology such as Wi-Fi smartphones, the internet, GPS and others, to get to a completed product there is the employment of some traditional processes and skills, one of these being the toolmaker (Stein, 2018). Historically, toolmaking can be traced back as far as the origins of human evolution when we first humans started to make tools to enhance our survival and development (Davidson and McGrew, 2005). The specific drawings (Figure 33). Enable the toolmaker to produce a machined tool that will act as a mould for heated material to be injected into then cooled and the process repeated.

Step 4. First iteration of enclosure and testing and adaptions to tooling if required.

Once completed the plastics were then sent to the manufacturers of the electronics which would conduct a final assembly and the testing both in house and external independent testing companies, specifically that performed tests for sport governing bodies. The in-house testing, the completed devices passed all tests and as such the company completed a European self-declaration of conformity (appendix 30.) this being a document that companies need to produce to allow them to place the “ce” mark on products. The “ce” marking on a product is a manufacturer's declaration that the product complies with the health, safety and environmental requirements in Europe. There are other types of document that are required in different parts of the word. However, the company were not seeking to sell products in other parts of the world currently and therefore chose not to add to expense of seeking any other certifications that can run into thousands of pounds (Wiengarten et al., 2017). Unfortunately, the external testing resulted in the device failing, when tested in sports governing bodies approved laboratory SportsLab (Scotland). Performing the tests as described in the sport’s governing bodies testing protocols for Rugby (appendix 31.) and Football (appendix 32.) this was due to the integrity strength between the top and bottom half of the enclosure (Figure 34).

This was most disappointing as it was felt that preparation for the testing was thorough and that the approval and certification would be a formality. It did highlight that as much as one prepares for a given task that there can always be an element of risk of failure. However, my view here is that this was a learning experience and from the words of Thomas Edison “I have not failed, I’ve just found 10,000 ways that won’t work”. Not that I want to perform thousands of tests, but it does further demonstrate the need to test thoroughly, and this will be taken into the latter stages of this current study when field testing is to be carried out. This failure rate is nothing new in engineering type projects and is viewed by many as an active learning experience (Freeman et al., 2014). Moreover, in an entrepreneurial experience such as the one in this study having an financial cost of the cost of the testing and any potential benefit to further enhance the students entrepreneurial learning experience (Bolinger and Brown, 2015). The costs of these external tests are not cheap running into thousands of pounds, but they are required and once approved then companies are allowed to place FIFA approval against their certified products by stating that they are approved by FIFA and can display the International match standards (IMS) logo on their product. This is similar to the sport of rugby with the International Rugby Board (IRB) approval given (appendix 31, 32.).

Figure 34. Safety testing external laboratory for FIFA and IRB approvals

V1 prototype Sportslab testing for FIFA and IRB approvals

These enclosures that failed it was identified that the area where the top and bottom parts of the enclosure would be reinforced therefore the toolmaker would adapt the tool to allow for this to be performed, with the result being a repeat of the eternal testing process.

Step 5. Pre-production run, assembly testing

Once modifications were made, the next stage was to produce a small number of devices to allow for assembly processes to be verified. The pre-production run involved 100 enclosures to be produced along with 100 electronics and the later described garments, so all elements of the product. This would also test supply chain and the whole process from order to delivery of completed product. Having manufacturers all based in central England did have a marked advantage as this reduced delivery times and enabled a smooth flow between each of the manufacturers and suppliers of the various elements of the product. An additional benefit was that this meant even with restrictions imposed due to COVID-19, that the supply chain was relatively uninterrupted which was effecting the supply chain in business globally (Golan, Jernegan and Linkov, 2020; Ivanov, 2020).

The assembly process was something that the electronics manufacturers were accustomed to performing and for the majority was fully automated, the only manual intervention was the sealing of the enclosure once everything was assembled. This involved gluing the top and bottom of the enclosure by hand, a cumbersome process and one that was to be automated by constructing a Jig that would perform this once full production commenced. The compelling reason for this was one of finance, as the cost of constructing bespoke Jig to perform a specific task is expensive. The cost far outweighed the benefit at this stage with such a small number of devices being produced (Roulet-Dubonnet, Sandøy and Schulte, 2018; Soufhwee, Mahmood and Abdullah, 2018).

Step 6. Field testing and modifications

The field testing involved being used in the field where the products would be used with the end user or consumer. This involved the finished devices being worn in situ in the garments by a participant who then performed various activity involved in sport, these were in the field in this case both grass and 3G synthetic surface multi use games area, commonly used in all levels of football specifically the latter in colleges and other FE settings in the UK and easily accessible. This was merely for the purposes of comparing against other types of devices and garments already being used in the industry, for fit, feel and look and safety (Figure 35). Participants wore different clothing including football kits, sportswear, hooded coats and sweatshirts with both male and female of differing ages including FE students (Figure 35). As they participated in football related activity. This was not evaluating the performance in terms of the data being produced as this would be conducted after all the three key factors identified earlier by the focus group were completed, these being the device, communication and housing as being described here in this study.

Figure 35. Fit and feel safety testing of products in the field

Following these field tests, it was found that the labels used on the reverse were susceptible to damage from excessive moisture (Figure 36). This damage could cause the labels to become loose and fall off, whilst this would not affect the function or safety of the device, it had displayed the device unique identification number and Quick Response (QR) code used to help with identifying faults and device history. Therefore, a further modification was made to the enclosure tooling to provide an indent to allow for the label to sit in flush with the enclosure and seal it, thus preventing any moisture being able to damage the label.

Figure 36. Moisture damaged from field testing and modified label

Moisture damage to label

Modified label

First full Production run

Following all testing, modifications and final approval sign off from company, a first production run of 1,000 plastic enclosures was conducted and then shipped to the electronics manufacturer ready for final assembly of the electronics to be finished devices.

6.3.2.2 Garment

As mentioned earlier a garment is required to allow for the device to be housed in a suitable garment that will allow for unrestricted movement by a user. It appears that these are pretty standard within the football and sports industry generally (Zieglmeier, 2017; Kim et al., 2019; Tierney and Clarke, 2019). However, these can vary greatly in price and the product being developed was such that it required for the garment to be affordable. Fortunately, one of the research student's mentors had worked in sports clothing for over 20 years and it was using the vast network of contacts and relationships developed over this time that helped to produce a suitable garment that was functional, innovative and affordable when compared to other types of garments used within the football industry.

The mentor introduced the project team to a locally sourced manufacturer of sports garments Sketch trading (Leicester, UK), this manufacturer had its own in-house design team as well as being experienced in producing bespoke products such as that being sought. Following a design brief and prototype build (Figure 37) ((appendix 33.) The garments were then field tested along with the devices for look feel and fit (Figure 35).

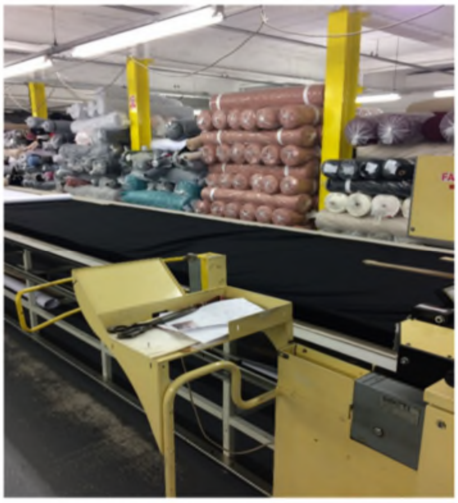
Figure 37. Sports wearable garment mentor design briefing and prototype build.

Mentor finalising design to garment

rear view of garment with pocket for device centrally situated

pocket with device in

Garment factory machining



cloth material for garments ready for cutting

These garments were produced in various colours and sizes so as to enable a multitude of users to be able to wear. In addition, the manufacturers were accustomed to producing unisex clothing, which was important given that the garments being produced would be required to have the adaptability to fit different genders. Therefore an recommended material by the manufacturers was used and design of the garments meant that these could easily be worn by different gender users (Figure 38). This was unique as it was identified by the mentor that this was something missing in this area and by producing a unisex garment such as this would be of commercial benefit as it would reduce manufacturing and supply chain costs. Thus, enabling the product to be cost effective and therefore more affordable to a wider range of consumers.

Figure 38. Unisex vest garment front, rear, side view

Garment front view rear view side view

Another feature that was developed within this garment that was also unique was the material used on the front panel being a mesh stretch material being breathable. The sports leisure wear market that has seen, like technology, many advances in innovation (ÖzdİI and Anand, 2014) as well as enhancing garments functionality from a performance perspective (Harifi and Montazer, 2017), comfort (Bartels, 2005), and cost (Harlin, Jussila and Ilen, 2020). Furthermore, a uniform sizing structure that allows for unisex use and reduced costs as the changes to manufacturing processes are minimised (Ledbury, 2018). The sizing structure being child, youth, small-medium and large adult. Whilst this element to the overall study as described here appears to demonstrate a relatively smooth and easy process, this was only possible due to the engagement of such an experienced and highly qualified expert as that of the mentor. This reinforces further the importance of networking and building relationships as was the case here and of employing snowballing technique in the recruitment process for a multi-faceted complex project such as this. With the snowballing technique being previously employed to good effect in study two with some of those recruited being retained further as the project was advancing and expanding. This being an important factor in business and industry to ensure growth and improved performance (Ulaga and Eggert, 2006; Rohrbeck, 2010).

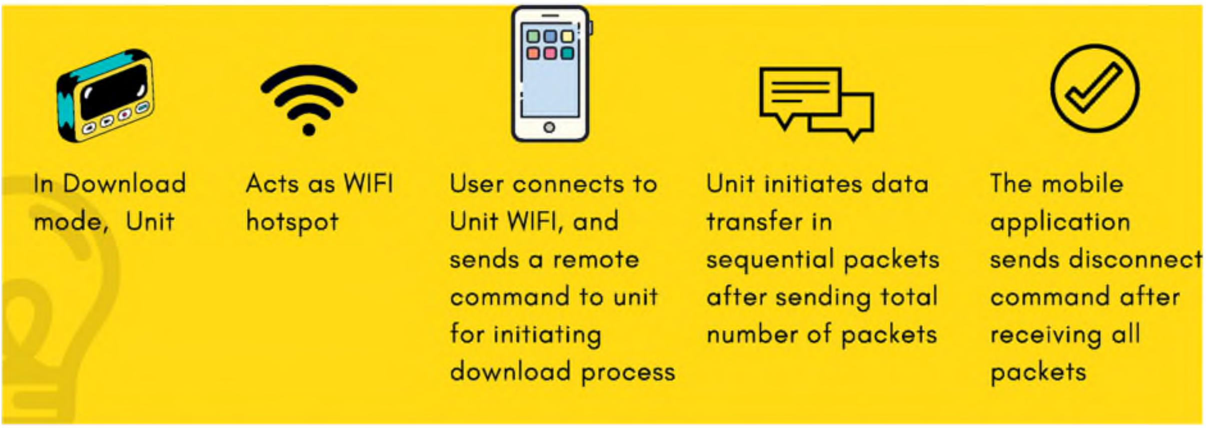
6.3.3. Communication

6.3.3.1. Overview

There first needs for communication from the device to a mobile device with an installed application, this being via Wi-Fi (Figure 39), this then transmits the harvested data to a cloud based platform (Vaquero et al., 2008), that then performs analysis of the data and then transmits the processed data to a user interface, in this case a mobile phone and finally for the user interface to then display information to a user via an installed application on their mobile device. The first part was covered when describing the function of the MCU and sensors, with embedded software developed to dictate the type, format and sampling frequency of data (Yanci et al., 2017; Rico-González et al., 2019) ready to be transmitted wirelessly via the Wi-Fi aerial to a receiving device, which in this case being a mobile phone. This would then transmit the data received to a constructed cloud-based platform for processing and analysis. Once completed, this processed data is then transmitted to either a web based platform or the mobile device application installed on the users mobile device, this then then displaying to an end user in a designed format that enables them to understand the data.

Figure 39. Data download process from device to mobile phone

DATA TRANSFER PROCESS downloading data From Device or unit to mobile application (data)

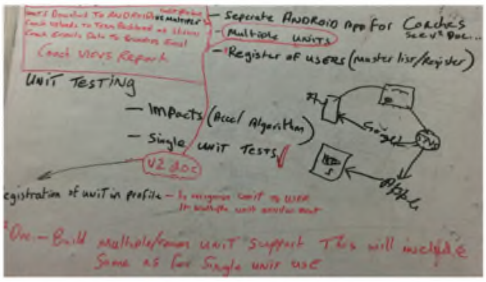


This then from the mobile device can then be transmitted to the cloud based platform for the data to be analysed and then transmitted back to mobile device to view the data

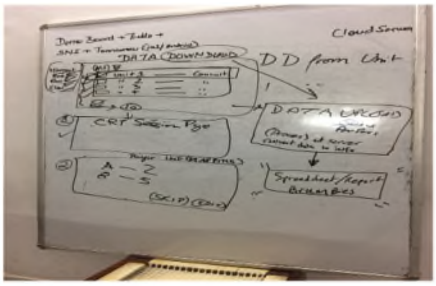
Again, this phase of the study was enhanced with the previous experiences in transmitting data from mobile device to a cloud based platform for analysis and post processing then transmitting back to a mobile device installed application and visualising data, used in a research study within academia (Tierney and Clarke, 2019). Additionally, in a commercial context in the previously mentioned presentation to a commercial enterprise and detailed further in (appendix 21, 22.). For this a software development company was employed PIN Services (Noida, India) that had experience of working in this area of developing mobile applications that required a user interface and communication with third party devices such as the device being developed. The first step of this process was for the research student and project manager to formulate the building, testing, integration and development of the software along with the other elements described. This required travel to the software offices in India as it was felt that it was needed to ensure that the software team were in sync with the vision of the project, further illustrating the international scope of this project.

The first meeting was similar to those with the other elements of the study and included the commencement of identifying the basic requirements and scoping out of the software development (Flora, Wang and Chande, 2014), including drawing diagrams similar to the method employed in the electronics phase the first being drawing of requirements (Figure 40).

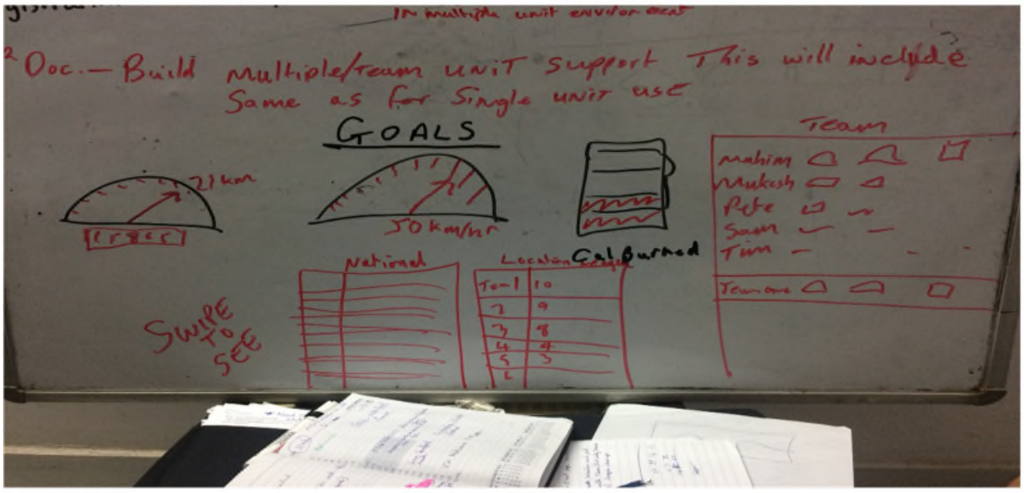
Figure 40. Software requirements drawings



Device – mobile App – cloud – mobile App



Data flow process



Visual display of data

Following this, a series of views of what the end user would see on their mobile device was required. This end user visual display and flow of the application was first constructed using a series of screen flows or snapshots of what the end user would see on their mobile device (appendix 34.). Once this overview and understanding of requirements was established, the remainder of the software development was conducted remotely and managed via the project management board (appendix 23.). The optimal method of developing and testing the software that presented, was to adapt the mobile application that was built and used in previous research (Tierney and Clarke, 2019), as was proven in the field under similar conditions as to the requirements for this current study. By adopting an approach of reengineering (Lopez-Arredondo et al., 2019) and reverse engineering (Canfora, Di Penta and Cerulo, 2011) methods is common, in such development of software applications (Santi, Guidi and Ricci, 2010; Charland and Leroux, 2011), as reduces cost and time to complete, as well as allowing for the software to develop and evolve with the other elements of the study in a timely manner (Bhavsar, Shah and Gopalan, 2020; Khachouch et al., 2020).

6.3.3.2 User interface

An understanding of the developing software is needed and how this was achieved also the description of its ability to interact with the other main element of the study being the electronics. Whilst it is not within the scope of this study to describe software engineering in its fullest sense, there is a need to detail how it developed from the early requirements drawings (Figure 40) to the end user interface. Like with the electronics development, software involves many elements, there is of course the starting point or foundation that everything is built from. This stage is known as the "source code" a readable text form that is inputted by a human in plain text, namely a programmer writes a programme in a particular programming language. This form of the programme is called the source programme, or more generically a source code, this being the only format that is readable by humans. When you purchase programmes, you usually receive them in their machine-language format, this means that you can execute them directly, but you cannot read or modify them. The programmer role is whereby they must translate it into machine language, the language that the computer understands. The first step of this translation process is usually performed by a compiler, the compiler translates the source code into a form called object code. Sometimes the object code is the same as machine code; sometimes it needs to be translated into machine language by a utility called an assembler (Elrad, Filman and Bader, 2001). Additionally, like with the V1 prototyping for the electronics, off the shelf code can be purchased and used (Gross and Kelleher, 2010). However, more common in projects that involve innovative and prototype electronics and communications there is needed a new original code written (Ji, Woo and Cho, 2008) and like other elements of this study, software too is continually evolving in the methods and approaches being used. An example being the automation of an evolving code (Lopez-Arredondo et al., 2019) and employing code optimisation techniques that reduce time and manual inputs at the programmer and compiler levels (Suk, Lee and Lee, 2020).

The start point of the user interface whereby the mobile application displays to the user, insights of the data that was uploaded from the device to the mobile phone and transmitted to an analysis platform and then receive back the data post analysis as earlier described, is the mid-point in the software road map. Given that the process of the data transfer and communication pathways is standard and uniform as with other technologies that employ Wi-Fi and mobile phones. This section will focus on how the data is processed and displayed at the user interface level, whether that be via a mobile phone or a cloud-based web browser. This will be described firstly the mobile phone and then the web browser, using a visual representation to better describe. The rationale for this is that the mobile phone would be the first view of the created insights from the data. The web browser then providing more scope for development and scalability of features that may be beyond the capabilities of the mobile phone. It was identified that the previous experience and study on this concept was from a single user perspective and as the study had identified that there also needed the capability for use in a team or group environment that this would need to be considered.

The conclusion from meeting to discuss this interaction process decided that due to the many different types of mobile devices that for team or group use, then a dedicated Tablet would be better suited and have a software application constructed that would perform a team or group collection of data, which would be similar to other types of wearable technology systems employed in football and FE industries. It was also concluded that this was more for a coach or lecturer use as is the norm in the industries, previously described in study one and two as being one of the barriers and challenges faced to use. As was restrictive and promoted a "silo" type culture with the coach or lecturer, dictating its use which was as a performance tool as opposed to an educational one and restricted to the confines of the sports performance departments, displaying data predominantly in paper form. For this study the technology required that individuals' data would still be accessible to the individual performing activity, by creating a solution that ensured the developed system was more individualised, accessible and better communication and feedback to an individual. Therefore, the individual mobile application and web browser would be constructed first with the team type application thereafter.

6.3.3.3 Mobile Application

As previously reported the mobile phone is an advancing tool that is becoming more common in educational settings (Artal-Sevil, Bernal-Agustin and Dominguez, 2015). The focus group along with the results from study two and literature reviewed directed the main metrics that were required as a minimum for reporting on, that could then be used to help develop the mobile application. Examples from the second study described in chapter five being;

"Heat maps generated from GPS"

"able to contextualise data as it disguises the maths to real life and connects with students"

" serve as a medium to promote interest in numeracy,"

The focus group having members with extensive experience in the use of wearable technology in a football and educational environment. The review of the literature on the complexity and confusion surrounding the vast array of metrics as well as the most commonly used (Halson, Peake and Sullivan, 2016; Seshadri et al., 2017; Malone et al., 2019; Rago et al., 2019).

Building out the mobile application required a constant flow of communication between the research student, the company and software team and by employing the project management tool as previously described, a dedicated section was created and used to monitor the progress of the many parts involved (appendix 7.). With mobile phones there is a vast array of types and operating systems. The two operating systems that are widely used being, Android operating system (Android) which is an operating system developed by Google and primarily used in devices such as mobile phones and Tablets, that are not Internetwork Operating system (IOS) which is the software used for Apple devices. Whilst both are similar, they do require different development, mainly due to the differing types of features (Novac et al., 2017) and security on the two different types of systems (Huh et al., 2017). An example of this is illustrated in (appendix 35,36.) on how to use IOS and also a trouble shooting guide with IOS, these being something the student placement was tasked to do along with other descriptive documents that would be part of the placement. This was helpful in that it addressed a component of improvement highlighted in the self-audit, that identified communication in different environments as being one of the areas for improvement and further detailed in the Personal Development Analysis (PDA) within the self-audit (appendix 1.) within Chapter one.

In addition to the screen flows (appendix 34.) a functional requirements document was produced (appendix 37.) to guide, but also simplify the basic requirements which was directed by the software team. They highlighted the potential confusion that can cause errors at the development level, that would prove costly in terms of time and financial increases if requirements and scoping documents were complex (Acar et al., 2017), or that consideration was not given for potential expansion of basic requirements by not producing a succinct description. As the study was seeking to build technology that could be used in educational settings there would of course be differing levels of capabilities and ages of potential users.

Having previously worked with different levels, ages and differing types of activity, further supported in the literature review, here was a problem presented. The example being speeds which as reported earlier, is one of the key metrics that all of these types of wearable technology employ. The differing speeds that are classified and descriptions given vary across wearable technology systems employed in football and detailed in a systematic review by Rago and colleagues (Rago et al., 2019) of related literature published between 2013-2019. However, this was limited to just professional football players and those over the age of 18 years old. Furthermore, this study categorised speeds into 6 different zones (1-6) similar to those as set out in Table 8. This current study rather than name these as zones (1-6) named these in the most simplistic terms these being standing, Walking, Jogging, Running and sprinting based on the literature. A default setting was set for these within the software platform, which users could then classify the speeds for these based on their individual thresholds as opposed to arbitrary ones that are commonplace in most systems.

With the wealth of studies identifying various speeds to enable thresholds or parameters to be determined, the majority of these were reported from professional senior male football players and there were differences reported in the speeds not only between zones but also within each speed zone classified and described Table 8. (Rago et al., 2019). This can be seen as a historical issue throughout the use of wearable technology in football (Bradley et al., 2011) and continues to show large differences within each zone or descriptor of actual speed parameters for the given zones from standing and walking throughout to sprinting Table 8. (Di Salvo et al., 2010). This is understandable given the costs and complexity of use, specifically in the earlier years as wearable technology was not widely available and knowledge around the use was scarce. Additionally, whilst there are a small number of studies reporting on speeds for female (Gentles et al., 2018) and junior (Gastin, Bennett and Cook, 2013; Buchheit and Mendez-Villanueva, 2014) players, these again were based on elite level players. Therefore, these arbitrary speed zones and descriptors are misleading to anyone outside of the area which these are based on and with the lack of scientific knowledge outside of the professional and elite level football does explain why so many find confusing and beyond the scope of their use. This limitation that exists within wearable technology systems is not restricted to speeds alone, as acceleration and decelerations are also based on these types of zones or descriptors. Even type of system employed (Ellens et al., 2021) highlighted in the literature review and in study one and two that the need to simplify, individualise and help with understanding remain difficult challenges. Specifically, the translation of data to give relevant and meaningful insights to the user, that is specific to them and their capabilities and not just outside the elite area (Malone et al., 2019).

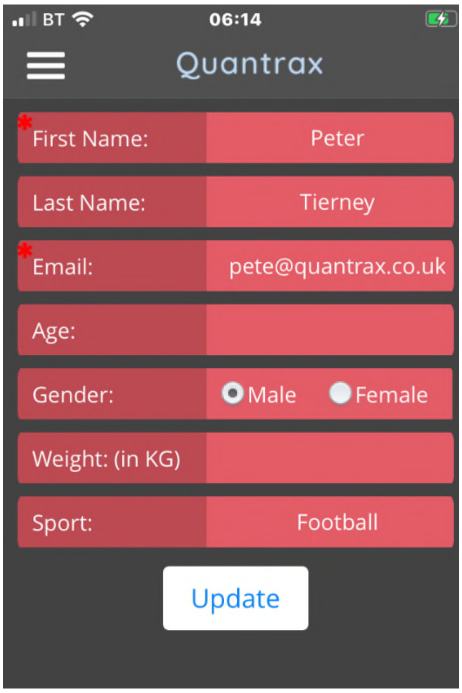
To better understand the speed someone is travelling at, information needs to be communicated within the context that they are in (Gebre and Polman, 2020). For example, Usain Bolt has held the world record for the 100 meter sprint for over 10 years and none could argue that he was definitely sprinting in that race (Gómez, Marquina and Gómez, 2013). There are few of us that could achieve anywhere near those kind of speeds that Bolt achieves, as in the world record race in Berlin in 2009 Bolt was clocked at 44.72 km/hr (Gómez, Marquina and Gómez, 2013), especially with differing levels of performer, type of activity participating in and age. Furthermore, as per the dictionary meaning of the word sprinting "*to run as fast as you can over a short distance, either in a race or because you are in a great hurry to get somewhere*" (English, 1976). It should be viewed that someone who is travelling as fast as they can are in fact sprinting regardless of the actual speed travelling at, yet this could be seen by a higher-level performer that they are travelling at a much slower pace than them and therefore not classified as sprinting. This perhaps highlights that appropriate use of language needs to be applied, so that the performer is able to relate to what they are doing, more that it would be better to allow the tool being used to measure what doing and then able to be calibrated in such a way that it becomes individual to that person and can change as they change, either manually or automatically or both. Therefore, rather than the actual Km/hr dictating the term it is the user who describes what they are doing, and the Km/hr is aligned to that.

Table 8. Speed descriptors variation across research

	Speed ($kmxh^{-1}$)	Description	Speed ($kmxh^{-1}$)	Description	Speed ($kmxh^{-1}$)	Description	Speed ($kmxh^{-1}$)	Description	Speed ($kmxh^{-1}$)	Description	Speed ($kmxh^{-1}$)	Description
Buchheit et al. 2017							14.4-19.8	n/a	19.8-25.2	High speed running	>25.2	sprint
Clemente et al.2019			0-6.9	walking	7.0-13.0	jogging	14-20	running				
Owen et al. 2017			0-7.2		7.3-14.3		14.4-21.5		21.6-25.2		>25.2	sprinting
Coutts et al. 2010	0-0.7	Standing	0.7–7.0	Walk	7.0–14.4	Jog	14.4–20.0	Run	18.0–24.9	Run	24.9–36.0	Sprint
Malone et al. 2017			0-5.0	n/a	5.0-10.0	moderate	10.0-15.0	high speed running	15.0-25.0	very high speed running	>25	sprint
Hartwig et al. 2011	0–1.0	Stationary	1.0–7.0	Walk	7.0–12.0	Jog	12.0–21.0	Stride	81.0–95.0 %	Sprinting	>21.0	Sprint
Suárez-Arrones et al. 2012	0.1–5.9	Standing/ walking	6.0–11.9	Jogging	12.0–13.9	Cruising	14.0–17.9	Striding	18.0–19.9	High-intensity running	>20	Sprinting
McLellan et al. 2011	0–6.0	Standing/ walking	6.1–12	Jogging	12.1–14.0	Cruising	14.1–18.0	Striding	18.1–20.0	High-intensity running	>20.1	Sprint
Austin and Kelly 2013	0–12	Standing, walking, or jogging			12–14	Cruising	14–18	Striding	18–20	High-	20–24	Sprinting
Barbero Alvarez et al. 2010	0.0–0.4	Standing/stop	0.5–3.0	Walk	3.1–8.0	Low-intensity running or trotting	8.1–13.0	Medium intensity running	13.1–18.0	High-intensity running	>18.0	Sprint
Hill-Haas et al. 2009	0–6.9	Standing/stop	7.0–9.9	Jogging	10.0–12.9		13.0–15.9	Cruising	16.0–17.9		>19.1	Sprinting
Castagna et al. 2010	0–0.4	Standing	0.4–3.0	Walking	3.0–8.0	Jogging	8.0–13.0	Medium-intensity running	13.0–18.0	High-intensity running	>18.0	Sprinting
Casamichana Castellano 2013	0–3.9	Stationary–walking			4.0–6.9	Jogging	7.0–12.9	Quick running	13.0–17.9	High-intensity running	>18.0	Sprinting

In order to allow for this, the system being developed included specific speed zones (appendix 37.), that could be set parameters, when a user was registering their details when installing the mobile application (Figure 41), with the full details of screen flow in (appendix 38.).

Figure 41. User registration details for mobile application



Therefore, within the functional requirements document (appendix 37.) details were outlined on ranges for speed zone descriptions for Walking, Jogging, Running and Sprinting. This would help in contextualising the numbers, by displaying so that the user and anyone viewing the data could better understand the meaning of the numerical values of various speeds travelling at (Collins, Carson and Cruickshank, 2015; Fox et al., 2018; Luczak et al., 2019; Nosek et al., 2020). A further metric that of High Speed Running (HSR) was also included, as this was a metric that was found to be common across the majority of systems, and is well documented in numerous studies as detailed in the literature review (Malone et al., 2017; Malone et al., 2019; Rago et al., 2019). Furthermore, the user with this system being constructed is able to input set parameters of Km/hr for the descriptors they are using based on their own individual experience of their performance, thus creating a more individualised system. Additionally, by incorporating editable naming tabs for these descriptors allows users to input in relatable language in their given environment or setting. A good example of this is with HSR, whilst this is a common metric in the elite arena as a zone between running and sprinting and incorporates elements of the two zones, it was highlighted in One - One interviews with focus group members that they use terms such as *"Cruising" "three quarter pace"* and "*Game speed*" in a similar fashion. In view of this, it is worthy of including this feature into the system being developed, as it would help connect better with users and other stakeholders as a language that they can understand.

It was identified by the software developers that it would not be possible within the current budget for the project to include these at the mobile application level and supported by the rest of the team, as there is still a scarce number of scientific studies that could clarify better what these were, and the language that users would understand clearly. However, it was able to be integrated at the web browser level (appendix 37.) and then once it was clarified on these zones in relation to the user that these could then be incorporated at a later stage or future iteration of the mobile application. Therefore, reducing the time and financial costs, once a framework of user interface, flow of the process to transfer and transmit data from the electronic device and registration process completed (appendix 39.), it then required testing with the electronics to enable the electronics to connect to the user interface installed as a mobile application on a users mobile phone (appendix 40.). This was then replicated for the team or group user application that would use a Tablet with the team application installed on (appendix 41.) this would follow a similar flow as the single user, with the main difference now that electronic devices are assigned to a team member so that the data would match with the user that collected data from a device. This would be performed via the web browser and instructions outlined on p21-24 of a constructed user manual for the web browser (appendix 42.).

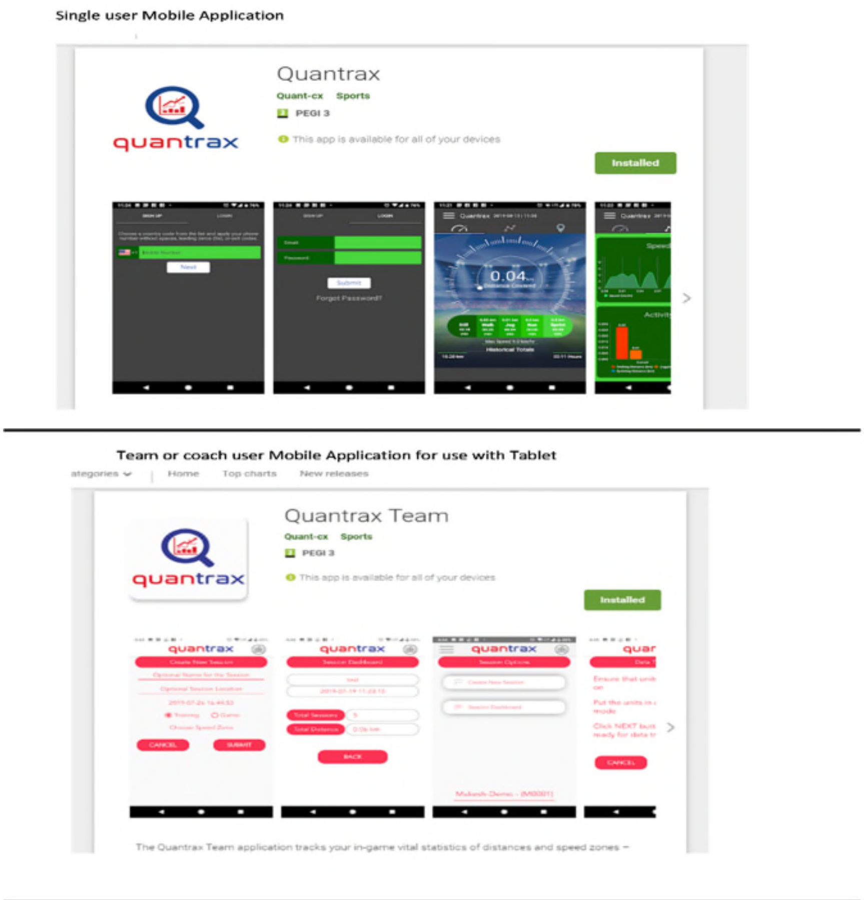
For live testing, at this stage required coordination with, the tester being the research student and the software development team based in India, this was performed using Skype with video link to the testing, the software team tracking the flow from electronic device to mobile phone to cloud and then back to mobile and web browser analytics (appendix 43.). This had to be preceded by a user logging in therefore, the user login was tested first (appendix 44.). In conducting in this way allowed the software team to sync each step so there formed a logical process that could be verified and then encapsulate within the programming of the software. This involved testing the communication not only with IOS and Android systems, but also the different operating system versions of which in 2021, there currently for Android is on version 11 and IOS version 13. Therefore, these various version releases required to be tested (Figure 42), before the application could be tested with the electronic devices and communications. However, only the last two software updates were considered, as historically, user uptake of software updates on mobile devices have been shown to be as high as 97% within the first three weeks of release (Mathur and Chetty, 2017). Additionally only the most popular mobile phones were employed for these tests being Samsung for Android and iPhone for IOS (Curran, 2018; Wieser, 2021).

Figure 42. Testing communication with different operating systems

6.3.3.4 Web browser

The web browser platform enabled the viewing of both individual and team user. It was also the location where more in depth analysis could be performed that was beyond the scope of a mobile device. The installed applications on mobile phones (Figure 43) are used by individuals who create data as per their usage of the application. Or with a Tablet to gather data from multiple users and able to view a summary of activity, either as an individual or team depending on if they use the single user application or team coach application.

Figure 43. mobile applications for single and team coach



A web based analytics platform provides ability to gather, compare, sort, search, plot charts and tables to understand the data from all dimensions and viewpoints. This provides ability to assess insights that are only available once all the data is viewed in cohesive manner rather than a standalone mobile application. However, as with this system developed, the platform did perform analysis from data transmitted via the mobile phone and displayed this back on the mobile application, being a method that is increasingly being employed in mobile application and interface development (Tidal, 2013). It was also able to accommodate much more information where users once registered could access much more information. A good example being a guide on how to use the electronic devices (appendix 45.) and even a video guide of how it all works from charging the electronic device and turning on, to downloading and uploading the data from a mobile phone, as well as viewing the data insights generated and displayed on the mobile application installed on a user's mobile phone (appendix 46.).

There were ethical considerations for this approach as the privacy of an individual user needs to be incorporated, especially within a system that interacts with a multitude of stakeholders as this system being developed would allow for. Therefore by restricting access to the web browser and preventing access to peoples personal information that may be stored on their mobile phone would protect their privacy (Papadopoulos et al., 2017) and security (Hayes, Cappa and Le-Khac, 2020). Additionally, an extra layer of privacy protection was required and therefore installed due to this providing location accuracy of user, which given the publicity surrounding a "Big brother" society catapulted to a heightened media attention with similar application such as track and trace types employed in the COVID-19 pandemic (Sharma, Dyer and Bashir, 2021).

These all being constructed by the research student placement, which is further evidence of areas identified for improvement within the action plan of the self-audit. Specifically, surrounding modes of communication outside of specialised area and relaying subject knowledge to a wider and diverse audiences. The production of these documents to then be published via the company web site and analytics platform and viewed to all potential users and customers was a proven success, that also included the construct of a trouble shooting guide for the mobile application, electronic device and web browser (appendix 47.). The web browser analytics being accessed via the World Wide Web on any device that was able to connect to internet.

At the following link https://quant-cx.pi314.in/users/sign_in#

One of the features of wearable technology that employ web based software platforms such as this one is the production of session reports, these are commonly in a pdf type format and can be manipulated to include all kinds of analysis, subject to the features included by the commercial companies supplying the technology (appendix 48.). As was identified in study one and two, these reports tend to be displayed in paper form on walls, with some delay on displaying of these and the inability to share the data in such a way that would enable its use for other curriculum areas or by a single user. Therefore, an additional feature on this platform was the inclusion of an export feature, that transferred that data once analysis had been performed into an Excel format, that would then enable users to manipulate and extract the insights gained into their own work. Whether that be for a single user performing their own individual analysis in PDF format (appendix 49.) or Excel format (appendix 50.) or as a team either in PDF as in (appendix 48.) or in Excel format (appendix 51.), even providing a report of an individual within a team (appendix 52.).

Additionally, the ability to export and download raw data could be useful for more in depth scientific analysis, such as HE research type studies, that would help better their understanding of the technology and outputs produced from all the sensors. Both, individually and collectively (Bower and Sturman, 2015; Attallah and Il-Agure, 2019) that would find benefit to this as the data would display the timestamp of each HZ for each of the sensors (appendix 53.). In this case, 9HZ being the number of data points recorded for each second, evidencing that data is not interpolated or extrapolated in a created algorithm by the commercial company supplying the technology. This demonstrating transparency to the user (Kim and Chiu, 2019), which is something that was highlighted in studies one and two, and review of the literature in chapter two that it was needed (literature review 2.3.2 Consumer sport). To help users understand how to use the platform and navigate through all the features, as is common in the majority of consumer products, a user guide or manual was created, this was performed by myself and also acts as a guide for the reader (appendix 54.). Additionally, there was also required to create a privacy & cookies policy (Degeling et al., 2018), terms and conditions and warranty (Luo and

Wu, 2019) for the company (appendix 55.). Once these elements were all in place the system and all the elements and various components involved could be tested in the various types of settings identified.

6.4 System testing

The system being developed required its gradual introduction into the final environments for which it is proposed to being used in, these being primarily FE type settings that involve football. As discussed, there are many components involved and the various elements need to sync in a multitude of scenarios, these being environmental, logistical and user interaction. The first of these tests required that the electronic devices were able to gather data and then be able to transmit to a mobile device and tablet. The second test then involved collecting data that was measurable, these included testing over a time period to ensure that signal was consistent and a further distance one. For this a simple shuttle course was set out at 20 meters between two cones (Figure 44) and a participant testing would walk with a device housed in the vest and wearing said vest switched on and connected to GPS satellites (indicated by green flashing on device as described in the how to use guide) ((appendix 45.), to the opposite cone and then turn around 180° and then walk back to the opposite cone. This was done five times, so in total 100 meters was travelled at a walking pace. This was then repeated at a faster pace that was more like jogging and running, with a total distance for the activity being 200 meters. The electronic device was then turned off ready to download later. Following testing of multiple electronic devices in this way, when downloaded the data was then cropped to determine the accuracy of distances travelled, speed travelled at and outline on GPS heat map. The test results were then collected and evaluated on consistency, accuracy, and reliability.

Figure 44. 20 meter shuttle layout

The selecting of this test was that it was a proven method to test accuracy, consistency and reliability of this type of tracking and having previous experience of conducting (Tierney and Clarke, 2019).

In total, nine rounds of testing were performed using 5 completed production ready electronic devices, these were used for the testing and this was carried out by the research student. This was reported in Excel format as this also enabled the field testing of the reporting software created on the cloud platform (appendix 56.). These tests were also expanded on by including faster speed of running, longer logging times, and different distance, the latter, a shorter 10-meter shuttle test in total being 50 meters. The reason for selecting a shorter distance as well as the 20 meter and different speeds, was that these replicates closer to the type of running patterns experienced in football (Iaia, Ermanno and Bangsbo, 2009; Gaudino et al., 2013; Rebelo et al., 2014). Inter and intra reliability was performed with results presented in Table 9 and Table 10, (Figure 45). The testing of the devices was also employed to test the software and reporting features both in PDF format and with Excel, there was the basic data as before and also expanded features (appendix 57.), to demonstrate the flexibility of the software with Microsoft Excel as this being commonly used in education. There also required the online analysis or deep dive of the data and visual description in the heat maps (appendix 57.). There was one final test at this stage, which involved a repeat of the aforementioned tests on a 4th generation football pitch, with users that included both male and female, different levels of performer, length of experience of participation in football and experience of the use of wearable technology, ranging from never used before to 3 years' experience of using, and ages range from 16 - 25 year of age (appendix 57.). This was to evaluate more closely, to the type of setting and various types of users that would be encountered if FE football related settings. With these in house tests completed the project could move to live field tests with targeted users, these being students in FE football related settings.

6.5 Results

Table 9. Interrater unit familiarisation and testing at estimated walking speed

Walking Familiarisation	**Familiarisation 1**	**Familiarisation 2**	**Mean**	**SD**	**CV (%)**
Unit 1					
Distance (m)	94.06	101.36	97.71	5.16	5.28
Walking (m)	43	13	28	21.21	75.76
Jogging (m)	51	88	69.5	26.16	37.64
Max Speed (km×h^{-1})	7.9	7.9	7.9	0.00	0.00
Unit 2					
Distance (m)	97.13	101.77	99.45	3.28	3.30
Walking (m)	35	15	25	14.14	56.57
Jogging (m)	62	86	74	16.97	22.93
Running (m)					
Max Speed (km×h^{-1})	7.2	7.6	7.4	0.28	3.82
Unit 3					
Distance (m)	96.64	100.05	98.34	2.41	2.45
Walking (m)	44	16	30	19.80	66.00
Jogging (m)	53	84	68.5	21.92	32.00
Running (m)					
Max Speed (km×h^{-1})	7.6	7.2	7.4	0.28	3.82

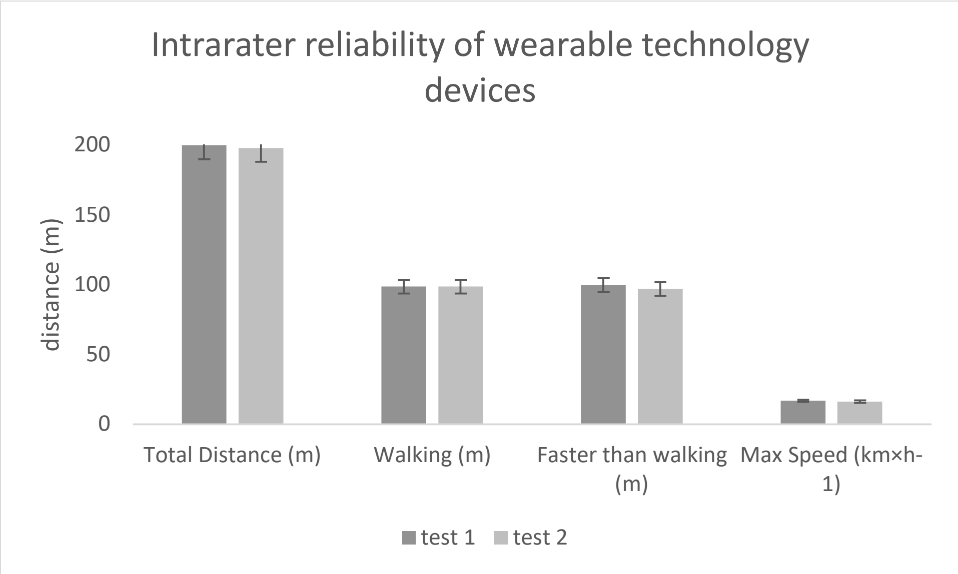
Walking Test	**Test 1**	**Test 2**	**Mean**	**SD**	**CV (%)**
Unit 1					
Distance (m)	97.05	100.97	99.01	2.77	2.80
Walking (m)	97	101	99.00	2.83	2.86
Jogging (m)	0	0	0.00	0	
Max Speed (km×h^{-1})	5.8	5.8	5.80	0	0.00
Unit 2					
Distance (m)	98.77	98.82	98.80	0.04	0.04
Walking (m)	99	99	99.00	0	0.00
Jogging (m)	0	0	0.00	0	
Running (m)					
Max Speed (km×h^{-1})	5.8	5.4	5.60	0.28	5.05
Unit 3					
Distance (m)	100.3	96.49	98.40	2.69	2.74
Walking (m)	100	96	98.00	2.83	2.89
Jogging (m)	0	0	0.00	0	
Running (m)					
Max Speed (km×h^{-1})	5.8	5.4	5.60	0.28	5.05

Table 10. Interrater unit familiarisation and testing at estimated Jogging speed

Jogging familiarisation	Familiarisation 1	Familiarisation 2	Mean	SD	CV (%)
Unit 1					
Distance (m)	90.13	101.35	95.74	7.93	8.29
Walking (m)	3	1	2	1.41	70.71
Jogging (m)	12	11	11.5	0.71	6.15
Running (m)	70	90	80	14.14	17.68
Sprinting (m)	4	0	2	2.83	141.42
Max Speed (km×h^{-1})	18	16.9	17.45	0.78	4.46
Unit 2					
Distance (m)	95.63	100.74	98.19	3.61	3.68
Walking (m)	0	1	0.5	0.71	141.42
Jogging (m)	21	10	15.5	7.78	50.18
Running (m)	75	90	82.5	10.61	12.86
Max Speed (km×h^{-1})	16.9	16.9	16.9	0.00	0.00
unit 3					
Distance (m)	97.49	101.4	99.45	2.76	2.78
Walking (m)	1	1	1	0.00	0.00
Jogging (m)	12	12	12	0.00	0.00
Running (m)	85	89	87	2.83	3.25
Max Speed (km×h^{-1})	17.3	16.6	16.95	0.49	2.92

Jogging Test	Test 1	Test 2	Mean	SD	CV (%)
Unit 1					
Distance (m)	100.4	101.26	100.8	0.61	0.60
Walking (m)	2	1	1.5	0.71	47.14
Jogging (m)	89	18	53.5	50.20	93.84
Running (m)	9	82	45.5	51.62	113.45
Max Speed (km×h^{-1})	16.9	16.2	16.55	0.49	2.99
Unit 2					
Distance (m)	101.73	96.07	98.9	4.00	4.05
Walking (m)	1	3	2	1.41	70.71
Jogging (m)	13	90	51.5	54.45	105.72
Running (m)	88	3	45.5	60.10	132.10
Max Speed (km×h^{-1})	16.6	16.2	16.40	0.28	1.72
unit 3					
Distance (m)	101.08	99.97	100.5	0.78	0.78
Walking (m)	1	2	1.5	0.71	47.14
Jogging (m)	18	92	55	52.33	95.14
Running (m)	82	6	44	53.74	122.14
Max Speed (km×h^{-1})	16.6	16.2	16.4	0.28	1.72

Figure 45. intrarater reliability of electronic wearable technology devices



Intra rater results were excellent with no significant differences for Total distance (TD) average 198.82meter Standard deviation (SD) 1.38 meter and coefficient of variation (CV) 0.69%. Walking average 98.67meter SD 0 meter and CV 0% and max speed average 5.53 km/hr SD 0.23km/hr and CV 4.17%. Jogging and running were grouped collectively as was because as described earlier, between test variance and users were significant as users travelled at differing speeds above walking pace and therefore named as faster than walking. Results for this were TD average 98.33meter SD 1.89meter and CV 1.92% and max speed average 16.45 km/hr SD 0.35km/hr and CV 2.15%.

Interrater testing results demonstrated no significant differences between the three devices selected and over the testing for walking and jogging TD average 98.32meter, SD 4.23meter CV 4.30%. On walking test TD walking average 98.67 meter, SD 2.8meter, CV 2.87%. Whilst there were no significant differences in TD, TD walking and max speed there were significant differences in the speed descriptor zones of jogging and running this was due to slight change of speed of participant which does further highlight the need to have these set to an individual's thresholds (e.g. Table 10).

6.6 Discussion

One of the risk factors of working with SMEs is the risk of a business failing, especially those that are fairly new, sometimes termed start-ups, which is companies that are under two years since creation. The cost benefit is one that needs to be evaluated and this is no easy task (Klimczak et al., 2017). The sector of wearable technology is part of the evolving 4th industrial revolution as described in the review of the literature and therefore the majority of these SMEs are in their early days. Innovation within these SMEs is seen as a key trait to those that are successful, therefore, the need for innovative practice is most certainly required, which is where collaborations with universities have been reported of most benefit (Apa et al., 2020).

In many ways, a previous experience was encountered in early 2019 when the SME electronics company being the technology industry partner failed, which resulted in a further company being employed and the company with the research student placement having to absorb these costs as well as seek another electronics partner to construct products. As was encountered earlier during this project, the second manufacturer of the electronics went into administration shortly after building the technology for this project. Thus, highlighting the fragility of this area, and risks involved with any SME specifically those involved in innovative technology such as that involved in this project. Additionally, there was also the unprecedented changes occurring globally due to the COVID-19 pandemic which had decimated commerce as well as bringing about fluid changes to virtually every aspect of life. With the market along with the technology moving at an unprecedented rate, which is reflective of the fourth industrial revolution that demands innovation and science. Specifically, research and peer review validation to keep pace,as has been seen science and the academic community is striving to but struggling to keep pace with these changes (Reijers et al., 2018).

Communication and feedback, were highlighted as being areas that were needed to be addressed if wearable technology were to become more accessible and employed in the industry of football and education. Specifically, the key area of knowledge sharing and translation, which has been identified in numerous studies, specifically in sport science (Bartlett and Drust, 2020), with practitioners many diverse roles and multitude of stakeholders internally and external to the organisation working in (Weston, 2018; Buchheit and Carolan, 2019). To help in this, the system developed has the ability for the user to rename metrics to language that they were accustomed to and also that these metrics could be adapted to be more specific to the user. This study has constructed such a system that can accommodate these and should now be deployed and tested in the environments for which it has been developed for.

<u>CHAPTER 7</u>

Research Study 4 “Act”

The application of a wearable technology system for use in a Further Education (FE) football related environment

7.1 Research orientation

Following on from Study three which provided a wearable technology solution and a potential product suitable for application in a FE environment. The next step was to "Act" and establish efficacy of its use in an applied FE context. The ability to report on if it can adapt to ever changing needs that present from an unpredictable live environment. Having features incorporated that allow for users to dictate parameters and use language that they can relate to is something that should have benefit to them. Also, with having conducted testing of all the components of the system developed should ensure that it will fulfil the requirements for use in a live applied environment. Therefore, it is hoped that the outcomes of this study will demonstrate how it can be used in an educational context as well as being used for performance purposes, within football related FE type settings. To help address the problems identified in study one and two in getting sport and education to collaborate far closer than previously. More specifically, surrounding accessibility, improved feedback, and communication, more individualised of the data being produced, increase student engagement and create more independent learners.

7.2 Study design

The design for this study consisted of three cyclical stages, which are briefly reported below:

Stage 1: Setting up the study via (i) observations at the identified ITP to monitor and evaluate current working practices, (ii) informal One - One interviews and (iii) small group discussions with key stakeholders being coaches, lecturers and students.

Stage 2: (i) a pilot study that comprised of a pre pilot assessment, (ii) an introductory presentation and orientation day surrounding the use of wearable technology (iii)The deployment of wearable technology for use in the pilot study.

Stage 3: (i) a three-week observation of the use of wearable technology and (ii) a post pilot evaluation from key stakeholders including One - One interviews.

7.3 Pilot study

7.3.1 Stage 1: Setting up the study

The educational institution selected for this study was an FE independent training provider (i.e., Strachan Football Foundation) ((SFF) located in Rugby, UK. The SFF is a government-funded education provider that offers full-time education and learning opportunities for aspiring young footballers. Established in 2011, it is generally regarded within both the football industry and education sector as an established ITP, that offers learners nationally recognised qualifications in sport, coaching and fitness. The choice for using this particular ITP was largely determined by a previous engagement with this educational provider during earlier stages of this portfolio of work. For example, in the second study, two of the industry experts that formed part of the focus group interviews were employed by the SFF. Furthermore, recent reports suggest the SFF are a progressive and open organisation (SCL, 2020), and despite not employing the use of wearable technology in their current curriculum offer, they were receptive to embedding within their course content. The decision to embed the use and application of wearable technology in one of the SFF taught modules was established following a meeting between myself and the assistant director of football in May 2020. The purpose of this meeting was to discuss an outline proposal for the pilot study and gain an understanding of what would be required from the SFF, potential educational outcomes, and a backup plan due to COVID-19 restrictions. It was agreed to proceed by first assessing the suitability of the venue and presenting to SFF staff, details of the study and how it would impact on current working practice.

As I write up this section of the doctoral portfolio, I am reminded about a presentation I have just delivered to the latest cohort (January 2021) of students enrolled on the professional doctorate with LJMU about my own research journey. During the presentation I described the many experiences that I had over the years, and how the self- audit and reflective practice has helped me identify the transferable skills gained along my professional doctorate journey and how this has expanded my current network of contacts. The research meeting, I had with the SFF assistant director of football is a good example of this, as my previous experiences of attempting to set up research projects in applied environments has resulted in barriers and resistance, and a perception that researchers need to be viewed with caution. Indeed, just to get to an initial meeting can involve many hours of writing letters to only have no response. However, in this case, it was a few phone calls and an invite to a coffee and a catch up that cut through much of the so-called red tape that can cause much frustration and delay getting a study approved. Whilst I recognise and support the need for formal stages and structure such as ethics and research proposals, I wanted to highlight the importance and value of maintaining established relationships throughout both my professional career and doctorate experiences helped enable access to the SFF.

To further assess the suitability of the venue and facilities, a requirements document was produced (appendix 59.). The requirements document was produced from feedback from the testing conducted in study three in FE type settings. Additionally, two site visits were made on training and classroom days to further evaluate suitability for an applied study to be proposed and introduce myself to staff who I had not met before.

Pilot Study

Prior to the commencement of the study there first needed approval from the ITP identified and the business supporting as part of the professional doctorate placement. Background information on the research project, proposed content and road map, as well as how this study could potentially benefit both the ITP and business were presented (appendix 60.). In addition to this, as is normal in business practice, a service level agreement was drafted and agreed (appendix 61.) and a detailed service and supports commitments document (appendix 62.) was also provided by Quant-CX Ltd the business providing the equipment, software and student placement being me. All of these documents and the logistics involved were performed by myself as being integral element of the placement, this was mainly due to my experience in the type of environment and people used to working with. The service and supports commitments document included all the details surrounding GDPR and legal requirements demonstrating certification or compliance with current legislation. Once approval from all parties was agreed the study was able to commence as follows.

1. Observations comprised of me spending five, full teaching days at the SFF shadowing the lecturers and coaching staff to understand the mechanics of the day-to-day operating procedures and to determine how best to incorporate the pilot study without compromising the learners' educational experience. This involved holding informal One - One and group discussions with staff to gain feedback into how the pilot study could be integrated into the existing curriculum design without affecting the modular learning outcomes. Being accustomed to working in this type of environment was not totally new to me, as I had some previous experiences of working in FE settings that supported young professional footballers in both academy and college environments. These informal discussions were not however completely unstructured. The conversations and discussions I held with the SFF staff were grounded in both data and findings established in this body of work as well as empirical findings elsewhere (i.e., Nosek et al., 2020, Rago et al., 2019, Luczak et al., 2019, Weston, 2018, Jones, 2019, Ahmed et al., 2018). As such, aims and objectives were designed to determine what experiences and perceptions staff had in the use of wearable technology. What ideas they had, so that they could be involved more fully with the process, this in itself being shown to have a beneficial

effect when creating an inclusive environment in study design and application (Messiou, 2017). By way of some examples, below are some responses I recorded during the pilot process.

"too much complex data"

"The metrics keep changing, I don't get it"

"Takes too long to get the information and I'm talking weeks sometimes"

"The data is never in context how am I supposed to understand and act on rows of numbers"

"Keep it simple, I mean how hard is it, I just want to know what they've done and what they need to do"

"It would be great if we could use it and have the info there"

"Yeah since COVID we are having to think differently now in how we keep tabs on what they are doing"

"Wearable technology is now integral to the coaching practice and we need to know and understand about it all"

These comments were all captured during the time I spent with the SFF coaching staff and senior management team. What was encouraging was that all were positive and receptive towards using as the technical director commented

"Being able to wear the vests the players will feel more like the premiership players"

And one of the coaches

"giving players this opportunity will back up what we are seeing as coaches"

In contrast the informal discussions with the teaching staff highlighted that football staff including coaches view participants as players whilst teaching staff such as lecturers view them as students resulted in comments including

"Anything that gets the students to relate what they are doing in the classroom to football is of benefit"

"Understanding that numeracy skills are used everyday and getting the students to want to do it is needed"

"Like everything nowadays, technology is being more and more used and if we can get the students to want to use it to help them attain higher grades and it engages them more then great"

"we have been starting to use mobile apps such as Strava to get some data for them to start to use for some of their learning modules"

These informal discussions provide some insight into the staff perceptions of wearable technology and suggests the 'silo' type culture earlier highlighted, exists between education and football. These insights provide some partial support and evidence for the findings reported in studies one and two. For instance, study two reported the dis-connect between coaching performance and coaching education as well as other curriculum areas. That said, it was encouraging that all staff reported on the increased use of technology as they seek to diversify in their approach to delivery of and assessment of students' progress, due to the restrictions imposed by the COVID-19 pandemic. Which has seen more remote learning (Lapitan Jr et al., 2021), as ITPs along with other FE settings have had many changes, including long closures that are seeing an unprecedented reshaping of all educational services not just in the UK (Kang, 2021).

One of the many benefits to informal discussions is people are more comfortable and involved, helping in building the trust and relationship with the coaching staff who are such an influential member of the support staff that students do try and follow suit. If coaches buy into the technology and importance of, then students will as well as is often the case in coach-player or student relationships (Culver, Werthner and Trudel, 2019). These informal discussion approaches are nothing new to coaches as it is an everyday part of their work with players and has been shown to be effective in improved performance (Davis, Jowett and Tafvelin, 2019)

2. This component of the study involved the recruitment of participants, a pre pilot study assessment through an online questionnaire, an introductory session on orientation and a PowerPoint presentation on the background of wearable technology, finally the deployment of the wearable technology system that had been developed in study three.

7.3.2 Stage 2: Participants and procedure for pre-pilot assessment

Out of a total of 40 students that were registered with SFF in the year one cohort, a total of 31 students were recruited that met the eligibility criteria and consented to take part, these being male aged 17.4 years ± 0.8years with experience of playing football at varying levels for 4 years ± 10 years. In addition, three full-time FE lecturers with a minimum of 6 years teaching experience ± 2 years that held the necessary teaching qualifications also agreed to participate. Two of the lecturers had direct contact with the students participating and were also part of the educational focus group, one of these being responsible for coaching a football team outside of college that also included 2 of the students recruited for the study. The eligibility criteria for participation was that participants had to agree to take part and provide informed consent by reading and signing a participant information sheet (appendix 63.) this was conducted through, Liverpool John Moores University (LJMU) Joint Information Systems Committee (Jisc) online Survey, this provided an automatic secure storage facility to store participants responses. All participants were reminded that they could withdraw from the study at any stage.

Potential participants on opening their email were instructed to read the participant information sheet, they were then directed to the anonymous online questionnaire. On landing on the study page they would then first have to confirm they were over 16, any who did not then the survey would end there. Once they had confirmed age, then a screen would display following statement "I have read the information sheet provided and I am happy to participate. I understand that by completing and returning this questionnaire I am consenting to be part of this study and for my data to be used as described in the information sheet provided" please answer to confirm you have read the statement and agree to it". If they agreed to it and answer yes, when they then press next, this would navigate them to the start of the questionnaire, if they selected no then the questionnaire would end there and they would not take any further part in the study.

Pre-pilot data capture

The online survey that compiled of the pre pilot questionnaire was conducted to gain an understanding of students experience and perception surrounding wearable technology. A total of 28 completed questionnaires were accepted for analysis, students were asked to answer a range of questions these comprised of binary "yes "or "no" response, multiple choice and single selection, and free text answers.

Of the data captured during this pre-pilot phase descriptive analysis revealed that 92.9% (n=26) responded that they were not currently using any type of wearable technology for sport or personal use and 75% (n=21) had never used any wearable technology before. The question on what they thought wearable technology in sport does, the free text responses revealed that 92.9% (n=26) felt that it was to track and or monitor performance. Some free-text examples included:

"It checks everything we do on the field"

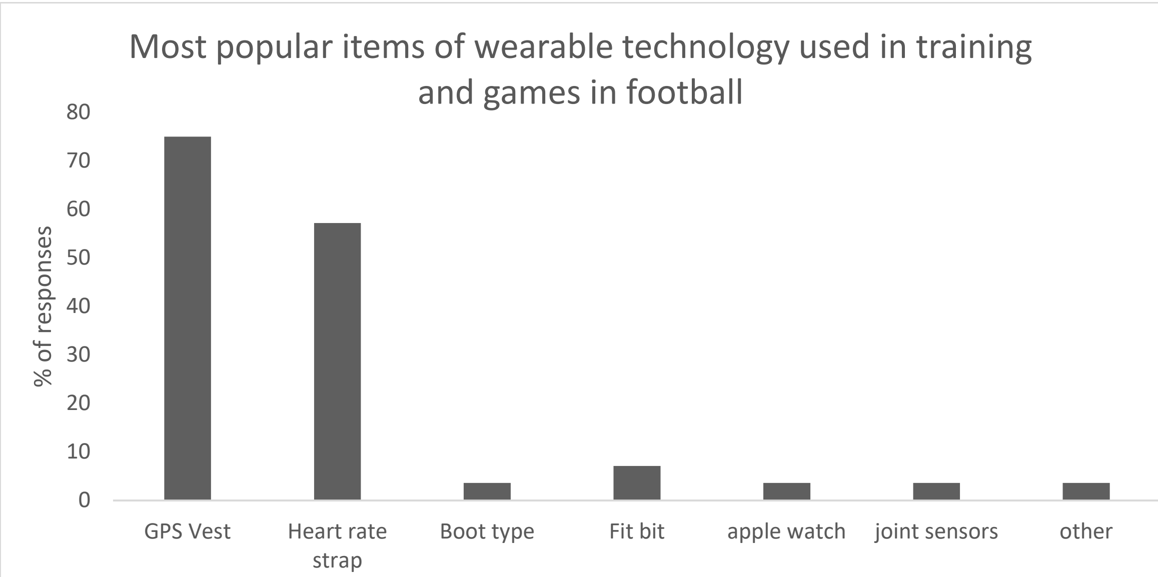
"Wearable technology that gives people stats"

"I think it helps to track your movement on the pitch and monitor your performance".

"Electronic devices that can be worn as accessories to tell you about your statistics a little bit more in depth"

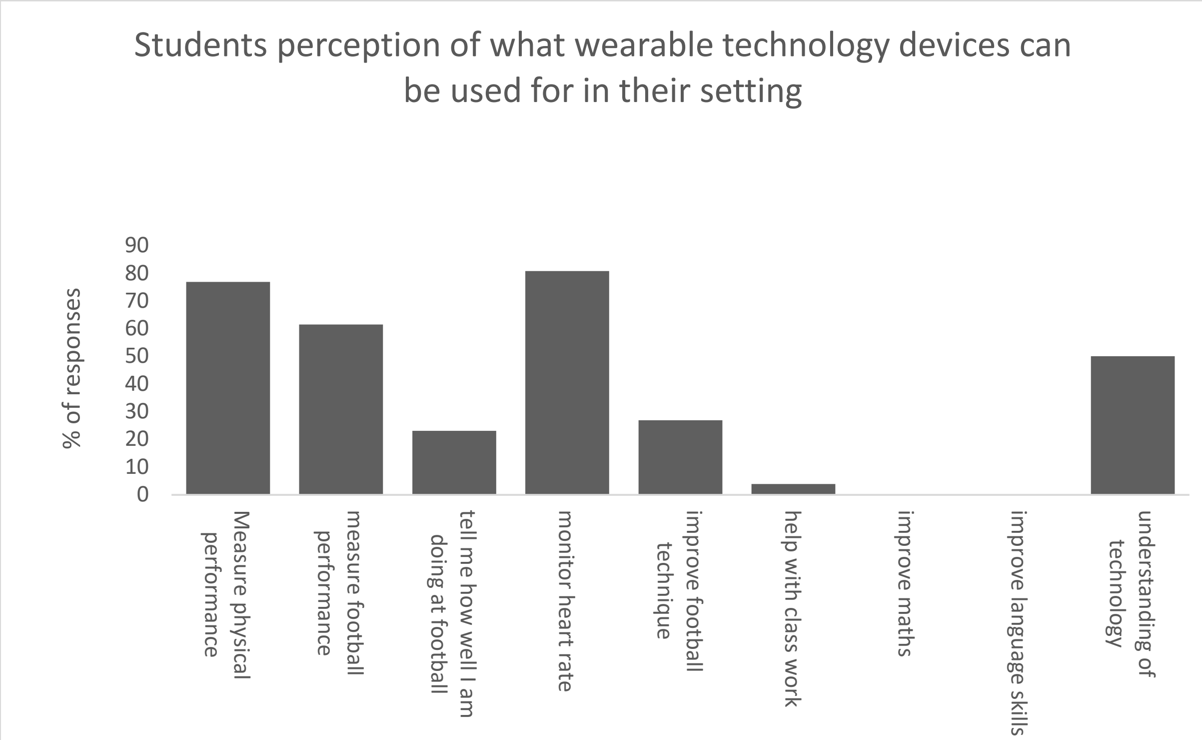
Of the type of wearable technology employed in football 75% (n=21) identified GPS tracking type devices and 17.9% (n=5) identified heart rate straps and 3.57% (n=1) identified wrist type device. When asked about what the most popular items of wearable technology in football were for use in training and games the majority of responses 75% (n=21) GPS Vest, 57.2% (n=16) Heart rate straps (Figure 48).

Figure 48. Student perception of the most popular items of wearable technology used in football training and games



Students were also asked how wearable technology devices could be used within their setting (Figure 49). In terms of student thoughts on, if wearable technology was good or bad in football 100% (n=28) felt it is good, if given the opportunity to use wearable technology for themselves, 92.9% (n=26) said they would and 7.1% (n=2) were unsure. Students were asked about amount of access to using mobile phones in the classroom 67.9% (n=19) said they would like access to remain the same as current access, 28.6% (n=8) said they would like to see more access and 3.6% (n=1) said they would like to see less access to mobile phones in the classroom.

Figure 49. Students perception of what wearable technology devices could be used for in their setting.



When asked who uses wearable technology in football 92.9% (n=26) players, 51.9% (n=14) Strength and conditioning coaches, 44% (n=12) Coaches, 29.6% (n=8) Analysts, 22.2% (n=6) sport scientists, 7.4% (n=2) Scouts, 18.5% (n= 5) Manager, even the Kit man received 7.4% (n=2), and media TV 3.7% (n=1), with heads of education 3.7% (n=1) and lecturers (n=0).

These results again provide some additional support to the findings in the previous two studies that there is this perceived disjoint between education and performance, or perhaps that football and education are viewed as unrelated. It is clear, students do not identify a link with wearable technology use and education, more that it just relates to football performance and direct football related departments. A good example of this is perhaps the question on identifying a link between who uses wearable technology in football, with two responses for the Kit man and one for the media whilst education received none for lecturers and only one for head of education. This further evidencing the need to increase understanding and knowledge surrounding the use of wearable technology and that education on this is much needed.

In part, education has made some advancements in this with the introduction of units of assessment around technology in sport in the qualifications. An example of this is unit 14 Technology in Sport and Exercise Science, of issue 8 Pearson BTEC level 3 national extended diploma in sport and exercise science. However, the learning aims have performance focus, with no clear outcomes on student learning across the curriculum and indeed no clear understanding of the technology being used in terms of capabilities, such as extending beyond the classroom. This focus was more task specific such as testing and data collection, also many of these are theory based as would have been the case with these students as the setting did not have access to wearable technology. Therefore, any knowledge learnt, would have students having no understanding of how that can be transferred to real world situation.

Embedding the technology: An introductory session:

In order to establish a smooth transition for the student use of the wearable technology an orientation and introductory session was designed. This involved a whole day for orientation (appendix 64.) and introduction to the proposed roll out of the pilot study to all the students that agreed to participate in the study. This included a PowerPoint presentation (appendix 65.) and familiarisation of the wearable technology being introduced as part of the pilot study and downloading the mobile application.

https://play.google.com/store/apps/details?id=in.pi314.quantrax.gps (single user) onto either their own personal phone or a mobile phone provided (Figure 50).

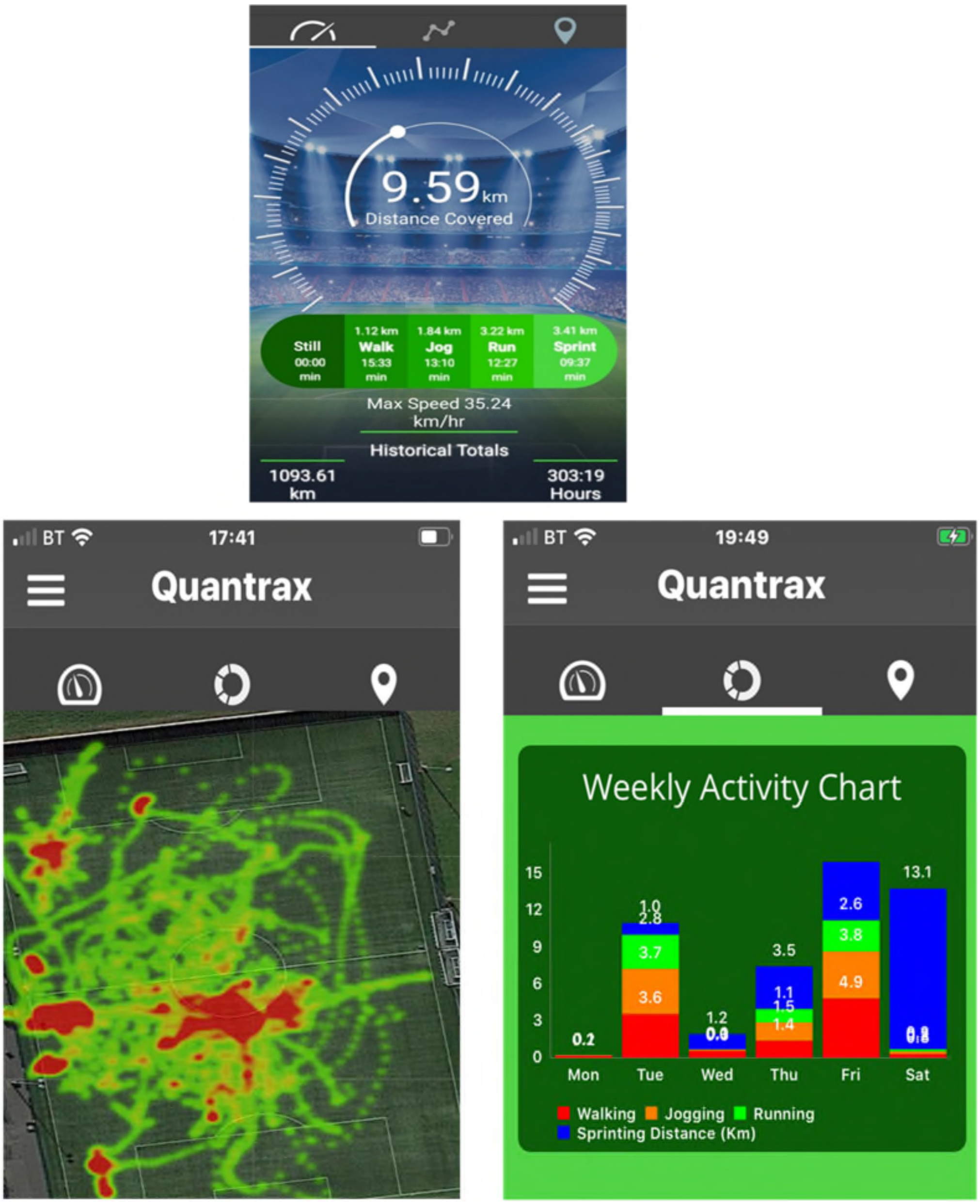
Figure 50. Student orientation day in the classroom and field

This was also posted on social media from one of the lecturers that commented.

"Excellent day today at Strachan FF. Today our first-year scholars trialled their first GPS vest in preparation of term 2 official roll out. Learners gain so much from seeing their hard work in training and competition in statistic format, as do the coaches".

Observations from coaches and lecturers concluded that the students appeared enthusiastic and more engaged with the wearable technology as they were instantly viewing what they had done therefore and appeared more informed regarding the data being produced. For example, data of a heat map of activity and their physical activity in charts, (Please see Figure 51). Physical activity data displayed on their mobile phones, enabled the users to view a how to view your data guide that was also displayed on a large screen in the lecture room (appendix 66.).

Figure 51. Screen shots of users data from activity displayed on mobile phones



However, perceived enthusiasm and increased engagement is something that is commonly reported when something new is introduced and after a short time this novelty factor can dissipate (Bower and Sturman, 2015). Interestingly more recent studies have found that students remain more engaged when using readily accessible tools such as mobile applications (Wishart, 2019), that promote a more interactive and active learning approach, specifically when designed with wearable technology and mobile applications (Attallah and Il-Agure, 2019). Moreover, in sports coaching courses an experiential learning approach has been shown to have far reaching benefits to students (Cronin and Lowes, 2016).

Deployment of the technology was carried out on this day as students were all given their individual electronic device, a charging disc (Figure 52), a link to a web browser, where they could log in using their credentials that they used to create a profile from downloading and installing the mobile application. Students were given a presentation on how to navigate the web browser including help features and how to guides to use for reference should any forget anything form the orientation day. Students were instructed to bring to college each day their device, charger and vest so that they could use during their football activity including training and games, additional vests, chargers and devices were available for those students that forgot or damaged theirs, but fortunately occurrences of this were rare. In addition, students were instructed that they were free to use as much as they wanted to outside of college. This was to observe if any used out of college for personal use and how they were using it.

Figure 52. Students' equipment for pilot study Vest, wireless charger and electronic device and mobile application link

7.3.3 Stage 3: Observation and post pilot evaluation

The three-week observation and data capture of the use of wearable technology was monitored by myself as I regularly attended the SFF campus. This was for both pragmatic and logistical reasons, such as been on hand to help with any technical problems, such as devices not working, Apps not connecting, or if students were experiencing any difficulties "logging in" or any other technical difficulties. During the first week recurring problems such as the students failing to charge fully the devices was rectified, however, this was deemed a product fault as opposed to student nonadherence. It was observed that there was no indication to battery life, for example if battery was low then there needed to be some mechanism to display to user this was the case, furthermore, when the device was fully charged then an indicator needed to be displayed to the user when devices were placed on chargers. This was feedback to the company and as such modifications to embedded software were made to indicate if low power (fast flashing light then turn off) or fully charged (flash green on power up). This did highlight the importance of product testing before proceeding onto full production of commercial product and launching into an open market place and the need for business specifically start up ones like the one supporting this project to be agile and adaptable in its approach (Cooper and Sommer, 2018; Thompson, 2019).

By having myself as the project manager and placed within the SFF for the pilot study, I was able to immediately input these observations to the project management board being employed for various experts to then evaluate what changes were needed for the product to then meet requirements for easier use (González-Cruz, Botella-Carrubi and Martínez-Fuentes, 2020) as well as the financial costs involved, again more evidence of the business academia relationship working and the entrepreneurial experience being gained by the student being myself (Berg et al., 2020).

Students were monitored daily when attending college and were actively encouraged to use outside of college. This was determined from students self-reporting and evidenced with live data from bouts of physical activity. In addition, match play data was collected as a team as well as the individual students. This data was accessed through the student dashboards. The team data was also relayed to coaches and lecturers in both PDF format and Excel (appendix 67.). For the coaches this enabled them to profile the team as a whole (e.g. positional characteristics, individuals, as well as various formations and tactics employed) as it is well established this is common practice in football teams employing wearable technology (Tierney et al., 2016; Hennessy and Jeffreys, 2018b; Malone et al., 2019; Rago et al., 2019).

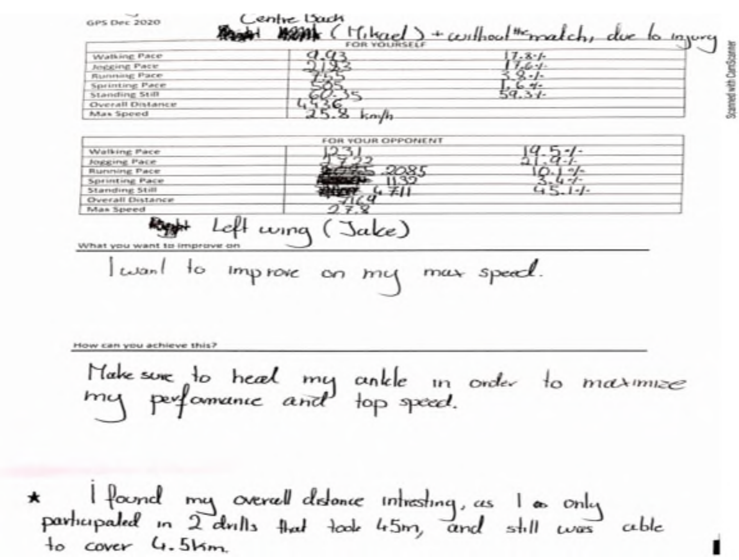
In terms of student engagement, initial observations suggested the students, once accustomed and familiar with its use, were fully engaged and competent in performing collection and analysis of data themselves. Furthermore, students were observed spending far more time after sessions discussing and reflecting with both fellow students as well as others including coaches and lecturers about performance data they had harvested from the practical coaching session (appendix 68.). Other observations included how students were keen to compare data with each other (appendix 69.), this even had direct interaction with coaching staff that were observed being actively engaged with students (appendix 70.).

From the pitch to the classroom

There was also evidence of the students transferring the wearable technology data captured from the pitch to the classroom. For instance, if weather was adverse then students would download and upload their data during lectures, this involved an increase in use of mobile phones to perform these tasks. The lecturers observed that students were using for this purpose and remarked that they did not need to encourage students as it was very much student led in their thirst for results for activity. As week two progressed I observed more interaction with the wearable technology and its transfer to the classroom, this was not just with football related performance but also in other areas of the curriculum such as numeracy. The addition of numeracy was driven from student requests, as they wanted to understand descriptive data, such as mean, mode and median averages in more depth (appendix 71.) and to calculate differences when comparing their results with a partner or opponent.

The task sheets constructed by the lecturers were specific to the units of work as part of students BTEC based learning, with this added numeracy element enabled lecturers to quantify better, students engagement with other curriculum areas (appendix 71.). The lecturers wanted to set a task to help them assess the technology being used and what benefits there would be to education. The specific units of work that the task related to being unit 19 and 27 Technical and tactical and Analysis of sport performance. Example being when students relate the data to what they have been doing and starting to perform much deeper analysis and develop a more critical thinking approach (Figure 53).

Figure 53. Student translating data into meaningful contextual insights.


GPS Dec 2020

Centre Back (Mikael) + without the match, due to injury

FOR YOURSELF		
Walking Pace	9.93	17.8 %
Jogging Pace	2133	17.6 %
Running Pace	255	3.8 %
Sprinting Pace	585	1.6 %
Standing Still	60.35	59.3 %
Overall Distance	4536	
Max Speed	25.8 km/h	

FOR YOUR OPPONENT		
Walking Pace	1231	19.5 %
Jogging Pace	2722	21.9 %
Running Pace	2085	10.1 %
Sprinting Pace	1132	3.4 %
Standing Still	4711	45.1 %
Overall Distance	7164	
Max Speed	27.8	

Left wing (Jake)

What you want to improve on

I want to improve on my max speed.

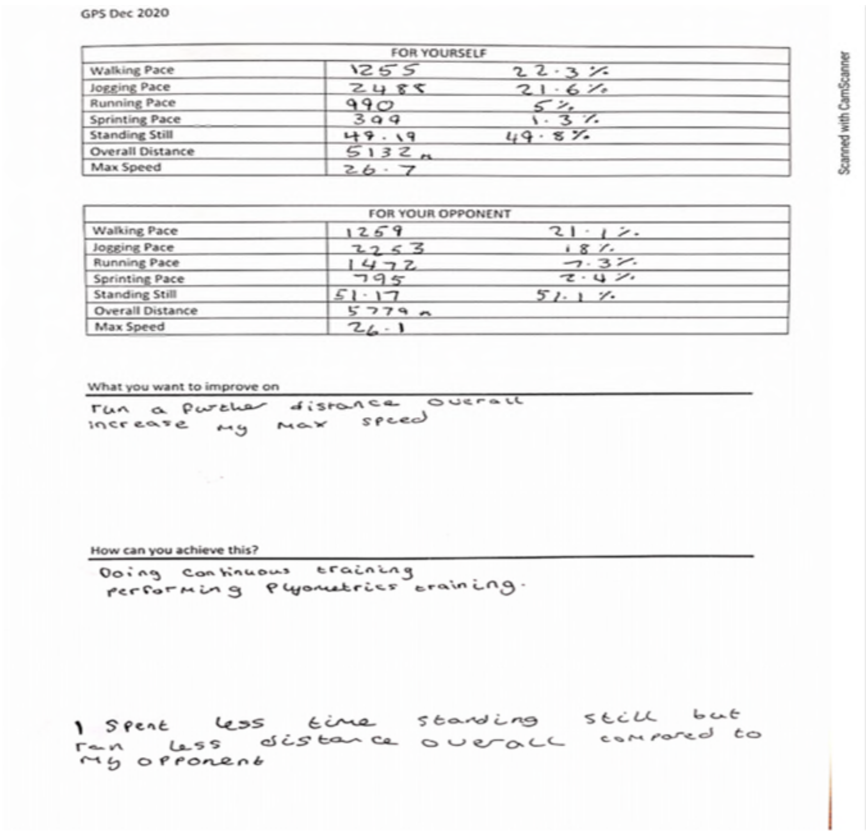
How can you achieve this?

Make sure to heal my ankle in order to maximize my performance and top speed.

* I found my overall distance intresting, as I only participated in 2 drills that took 45m, and still was able to cover 4.5km.

Also, in developing numeracy skills to better understand what they are doing, as in the example in (Figure 54). That illustrates the student calculating the percentage of time doing activities and then explaining in their own word what that means to them and what they want to do to change.

Figure 54. Developing numeracy skills and contextualising into meaningful language



GPS Dec 2020

FOR YOURSELF		
Walking Pace	1255	22.3%
Jogging Pace	2485	21.6%
Running Pace	990	5%
Sprinting Pace	399	1.3%
Standing Still	49.19	49.8%
Overall Distance	5132 m	
Max Speed	26.7	

FOR YOUR OPPONENT		
Walking Pace	1259	21.1%
Jogging Pace	2253	18%
Running Pace	1472	7.3%
Sprinting Pace	795	2.4%
Standing Still	51.17	51.1%
Overall Distance	5779 m	
Max Speed	26.1	

What you want to improve on

run a further distance overall
increase my max speed

How can you achieve this?

Doing continuous training
performing plyometrics training.

I spent less time standing still but ran less distance overall compared to my opponent

Scanned with CamScanner

Week three was monitored remotely due to increased restrictions from the everchanging, perhaps fluid situation that had become more common due to the COVID-19 pandemic, still impacting on education as was similar to all aspects of society. Lecturers assigned tasks that were in keeping with previous teaching in previous lockdowns. Whereas coaches this time, prescribed physical training that they monitored by accessing the web browser platform to check that students were logging data and acting as a form of register of attendance of sessions.

Once the coaches had become accustomed with all the functions, we then performed a session online to help set up more individualised speed zones and descriptors as described in study three. This was conducted over virtual meeting room and involved screen sharing using a trial-and-error approach (appendix 72.). This was seen as an important breakthrough in both coach involvement and coach development, as it was educating coaches on the capabilities of the wearable technology along with the various adaptable functions. I feel this should be seen as moving away from the dictatorial approach as so often used in developmental football as previously reported (Jones, 2019a) and towards a more inclusive working environment, with buy in from coaches as now better understanding through exploration and analysis of more recent and accessible data. This very much in keeping with blended learning approaches being adopted in FE, as has found that student centred and led such as this type being conducted in the pilot study, has much support that it has a beneficial effect to students enhanced learning experience (Dear, 2017).

7.4 One - one interviews

The final components to the pilot study were One - One interviews, with students, coaches and lecturers (appendix 73.) these being more informal. The student feedback was one that students explained that they were enjoying using something that was enabling them to use out of college for their own use and then being able to use the data in the classroom as part of their ongoing coursework. The system created had proven to be more user friendly than other types of wearable technology that some had experienced before. Students reported that it was simple to use and by using the mobile phone as the tool to download, upload and view data met that it was far more accessible than anything any had used before. Moreover, was the interchangeability of single and team user which meant that coaches and lecturers were able to view collective as well as individual data and students were able to continue to view their own data without the need for any exporting or copying of data, this along with the other comments demonstrating that the features that was determined by the focus group had broken down the barriers to use.

A further benefit that was not envisaged was that of the change in current coaches' approach to the employment of technology in their own development. Coaches were now starting to adapt football training that was more position specific and individual to each student based on data analysis from use of the wearable technology. This is encouraging as it further advances coaches development and being viewed as helping to quantify better the previous subjective viewpoints that can be controversial. As evidenced in video (appendix 70.) and feedback from coaches, that having the wearable technology used in this way was promoting more informed discussion with students on performance and a better contextual understanding of the data being produced, this being identified in numerous studies as something much needed (Weston, 2018; Cushion and Townsend, 2019; Jones, 2019a; Luczak et al., 2019; Malone et al., 2019; Nosek et al., 2020).

This did address some of the comments in study two that highlighted for use in education football coaching, examples being,

"The educational aspect of wearable technology is limited in delivery currently but good to show coaches"

"make coaches aware of how wearable tech can be used to enhance their coaching"

"More understanding of how to make it more educational would be beneficial"

"*I do not believe the link between technology use and tactics is understood partly due to lack of education of coaches"*

"Technology is unable to identify and/or improve so don't change it if it's working".

"*Able to create a player without the use of wearable technology"*

Following the deployment of the wearable technology and training in the web browser functionality coaches feedback was more positive, examples being

" being able to monitor remotely what players are doing makes my life so much easier if they train they play, its that simple"

"accessible and instantaneous for me and the player has changed our post game and training conversations as we now have data we both understand and can talk about to help inform what we do"

" feels like I'm communicating less yet giving them (players) *more information, if that makes sense?"*

"Far easier now to identify weaknesses or health concerns and act quickly"

"Finally numbers that mean something as we are able to use our own language and name ourselves and determine what is relevant"

"I've been using it myself and found that I am able to relate better with the players when talking about the data"

Whilst the main focus of this study is not coach education, it is important to recognise these findings, as some of the current participants may well progress into a career in coaching. There is currently much literature surrounding coach education and coach relationship with sport science in football (Cushion, Armour and Jones, 2003; Abraham and Collins, 2011; Barrett et al., 2018; Stonebridge and Cushion, 2018; Hall, Cowan and Vickery, 2019; Nosek et al., 2020). Additionally, the importance of coaches requiring a broad range of transferable skills and attributes, more so than merely possessing a specific set of skills (Holmes, 2013). Therefore, within the context of the college this is more around coach learning (Maclean and Lorimer, 2016).

This engagement by coaches with technology and the resulting feedback from use has evidenced the efficacy of in an applied environment, which was something that has been missing in research (Cushion and Townsend, 2019). This informal learning was an unexpected outcome from this study, yet a very important one (Rogers, 2014). I think this demonstrates the need for informal learning such as this especially in a fast paced area that has been reported earlier, with technology advancing and its use, growing faster than the development of theoretical frameworks (Stoszkowski and Collins, 2014). The need to investigate this further and perhaps look to integrate with coach education could be of advantage and supports that of previous research into coach education and technology (Cronin and Lowes, 2016; Cushion and Townsend, 2019) as well as general education (Bower and Sturman, 2015).

It is common for coaches within FE to have more than just a coaching role, with many being the lecturers as well delivering multiple aspects of students education, specifically those relating to courses that are focused around football and coaching. Additionally, this may explain why so many coaches have used the data from wearable technology in a way that is counterproductive to the development of players (Jones, 2019a; Kohe and Purdy, 2019) and coaches as well, without having an deeper understanding of what the data actually is reporting (Brink et al., 2018). As the saying goes "its not the numbers that lie, but the person communicating the data" and "lies, dammed lies and statistics"(Seife, 2010), becoming a sort of lost in translation scenario. With many sport scientist specifically those in charge of wearable technology systems within football clubs being either early graduates or on studentships (Malone et al., 2017; Hennessy and Jeffreys, 2018b; Lacome, Simpson and Buchheit, 2018; Buchheit and Carolan, 2019), then it could be very easy for them to fall into informing coaches on what they want to hear based on what coaches have said they want to know. Very much seen in methods of recruitment where a cognitive bias approach (Burhanuddin et al., 2015) is employed by coaches to impart their opinion on others (Toner and Jones, 2016; Jones, 2019a).

It has been reported in the past of wearable technology being manipulated to conform with a coach's or other persons of influence own viewpoint (Collins, Carson and Cruickshank, 2015;

Jones and Denison, 2018). I have from my own experience observed many placement students often agreeing with coaches to gain favour and improve chances of employment than actually report the data as it is being produced. In the aforementioned study by Jones and Dennison (2018), whereby the technology is used to gain more control over players being coached is nothing new and is seen by many ill-informed coaches as integral to improved performance (Denison, Mills and Konoval, 2017). This being compounded further with commercial companies supplying a multitude of different metrics that also adds confusion and conflict among staff (Carling et al., 2019; Malone et al., 2019; Rago et al., 2019). Supported further being reported that knowledge translation and its communication is much needing to be developed (Fullagar et al., 2019; Bartlett and Drust, 2020) and that we should now look at being more data informed than data driven (Gamble, Chia and Allen, 2020).

This was followed up one month later with a further One - One interview (appendix 74.), with the lecturer who was also one of the focus group members to provide an overview and evaluate outcomes of the pilot study. The lecturer being interviewed had spent the 1 month prior to the interview, investigating the impact of the pilot study, by holding meetings with other lecturers, coaches and students themselves, this ensured that all stakeholders views were onboarded and conveyed during this interview. To evaluate and gain clarity to support study findings the interview was semi structured containing questions as follows;

- How is wearable technology viewed post pilot from all stakeholders.
- The effects of use of the wearable technology system developed, on student engagement, can you identify any transfer from use in sport to classroom and give example of
- identify any extended use away from college and if so, what impact its use has had on student learning and attainment levels in education.
- What impact it has had on student football performance.

In addition to these, I wanted to evaluate the impact in other related curriculum areas these being

- Numeracy,
- Language,
- Information technology,

It was pleasing to hear during the interview that the enthusiasm from students, lecturers and coaches was still as high as it was when first introduced. During the month since the pilot study there had been a further National lockdown that included closure of education, this meant that during the month time lapse all contact with students was via remote technology and also that any physical training prescribed by coaches was also having to be performed individually away from the facility normally used. This did then mean that coaches were having to have more of a reliance on using the technology to monitor what students were doing. However, as highlighted in the interview, the coaches set the students a “sporting Excellence framework” and gave them specific running activities that the coaches then could monitor progress. It also served as a register to quantify attendance and answered in part the identification of extended use away from college, this being further supported prior to the national lockdown as some students also played football at weekends for local teams, they were using their devices to record activity from the game, and when in college were observed discussing their data as well as result of game.

With this increase in use away from the normal college day led to a learner growing in independence, all be it imposed upon due to the enforced restrictions as a result of the COVID-19 pandemic again gripping the UK like most of the rest of the world. However, the system developed was accommodating this method of learning as well as the additional benefit of being able to monitor remotely by coaches and lecturers providing quantifiable evidence. All this without having to get the students to do anything outside of what they would normally do other than wear their vest and device and download the data from the device post activity. Thus giving the students the results of their own performance and the platform to conduct live analysis as deep as their enquiring minds take them. I have used the term learner here instead of student as feel that coaches, lecturers and students were all learning. Coaches were beginning to be creative with the framework constructed and integrate more into their practice which also led to inspirational engagement of students and better interaction with lecturers. All leading to a more interactive environment this perhaps being more a sociocultural shift in attitudes and approaches, further expanding on the impact of inclusion of an effective wearable technology solution such as that deployed for this current study(Crook and Gu, 2019; Kinney et al., 2019).

This was further highlighted in the interview with the interviewee remarked that students were gaining a better understanding and performing informative assumptive assessments by making attempts of putting into qualitative terms what they were getting from quantitative data. In addition, there were observations made of students being more creative in what they were doing as they were not simply just completing set distances. They were now starting to perform different types of running that was more replicate of what they were doing during match play and training when at college, this was because they had the data from match play and training. This creative thinking is important in developing students' problem-solving skills and opening up to new experiences as well as a method to quantify these areas better (Stupple et al., 2017; Wechsler et al., 2018). Becoming more independent learners as being allowed to have more ownership of their individual development as their knowledge and understanding develops.

Coaches to, it could be argued were becoming more independent learners as they were employing the data as part of their coaching process and bringing context to the numbers rather than just comparing one metric such as total distance covered, which when reported in isolation is an ineffective measure (Malone et al., 2019; Ellens et al., 2021). To aid in this I constructed a template manual of training drills that coaches could use to help integrate the technical, tactical and physical components of their practice as well as keep for their own use as their education continues (appendix.75.).

Numeracy

Numeracy has long been identified as being a high priority developmental area across all of FE, in helping to understand some of the barriers the interviewee explained that many student enrol being classified as level 2 learners. Here are people that have had at least 5 years studying maths and at the end of secondary school have not achieved a pass grade. Therefore trying to educate and teach maths again to a disappointed, demotivated and reluctant 16 to 17 year old is understandably difficult. Therefore anything that can help them understand where they will use maths that they are interested in would be of benefit. This is where the system was of most benefit as students could relate to it and recognise how it fits into what they are interested and motivated in, this was evident from some of the feedback given when asked,

"Right OK, now I can understand why and how you work something out"

"I can see why I need to know the average, why I need maths to help me on the pitch"

"This isn't like the maths classes I did at school"

by having number that were relatable to what the students were doing in the field, students viewing data as not just numbers on a page, but now these numbers related to what they had just been doing, still fresh in the mind (Apino and Retnawati, 2017), helping to give the student a deeper meaning and understanding of numeracy skills and working with numbers.

Language

By performing a comparison analysis in the example task provided (appendix 71.), as well as their own and continuing on, throughout the study, lecturers deemed students as working towards distinction level, this was assessed as attainment was increasing as students were becoming more easily able to identify strengths and weaknesses and to describe these giving context to their work. Furthermore, it was seen as the students were developing critical thinking skills which is very hard to entice students into and even harder to quantify (Shively, Stith and Rubenstein, 2018), this supported further with examples from students being:

"Well, what could I do for somebody else?"

"How could I apply this if I was the coach?"

" why do I have to do it like that"

There was some evidence of the "What, how and why" the corner stones of critical thinking and evidence that students using wearable technology in this way are developing these (Stupple et al., 2017). This engagement through game like activity is nothing new (Clarke et al., 2017), however, this does provide evidence that a product such as the one developed for this doctoral project can develop students more holistically across a multitude of the curriculum including skill acquisition and transference (Weil and Eugster, 2019), thus potentially preparing them for the employment market (Teng et al., 2019).

This also linked with student engagement as lecturers reported on students starting to apply to real life theoretical issues, about alternative employment opportunities that they could see how they were improving and that it was their own and able to use this experience to get better in life holistically and not just playing football, and further with a student comment;

"Right, I can actually go down different avenues now not just playing or a straight line"

What underpinned this was that the lecturers reported that students were able to access immediately, there was no waiting around, no trying to remember what they did and when, no complex reports or jargon and being able to view and analyse their own data to gain meaningful insights, that they the students could identify with, literally coming off the field and straight into the classroom wanting to learn.

7.5 Real world impact

In view of the aforementioned pilot study and to further evidence this product that has been developed and evaluated in an academic study here in study four. This project now goes one step further and evaluated the constructed and piloted system in the marketplace for which it had been built for use in. To achieve this, the commercial enterprise set up Quant-CX Ltd there was a further 500 devices produced and 1,000 vests, along with increasing the bandwidth of the software platform built to cope with increased demand. This would also enable the company to conduct early adopter sales to further develop the product to gain traction in an competitive open market and not just for FE settings that included football, and other sports as well. Many of the customers were recruited in a similar fashion to that employed in study two for the focus groups using the snowball sampling techniques. Ranging from recommendations from my network and the trials and pilot study. Some notable ones from other sports industry being Wasps rugby union Coventry UK for use within their academy with their elite player development group that involved monitoring of players remotely who were based at various colleges and schools scattered throughout the UK. Some of these being within the national teams' squads. With the programme lead commenting

" This has better allowed us to monitor better the players and also it had shown that the players themselves are taking more ownership n their own development"

Connor O'Shaughnessy Lead Pathways Strength and Conditioning coach Wasps

Other clients in rugby included Cambridge rugby club that was an amateur community club for use with their teams from youth to adult. Then in football there was clubs from adult grass roots that did not have an educational branch attached or involvement with FE (Northwich 1874 FC)

"Its not just about being able to afford this type of technology its that we can understand it and use it to help performance, during lockdowns we were able to get players using individually, they wanted to learn"

Wayne Goodison Head Coach Northwich 1874 FC

A further example of how adult grass roots football has looked to use is illustrated in (appendix 76.) an article printed in the match day programme for Stretford Paddock Football Club. This provides further evidence of the aforementioned informal learning, earlier in this chapter, where coaches and players have performed their own investigation into uses and benefits to help them with their performance.

One example of how the system has been used in FE was with Thomas Bennett Community College Football Academy (TBCCFA) which purchased the system through the business offering of Quant-CX Ltd. This being

"*At the Thomas Bennett Community College Football Academy we have found our Quantrax GPS system to be a great way of blending our learning in areas away from the original performance data. We use the convert the information into Microsoft Excel format feature so that it can be easily accessed and adapted for our Functional skill maths and ICT students.*

Once we have the data maths tasks become far more relevant and enjoyable to the students themselves as opposed to basic past papers. Our ICT students use and manipulate the Excel files to replicate skills required in their exams but also suit our performance analysis sessions that we run with the players.

We have found a massive increase in engagement in both groups of students as they are encouraged to use skills and techniques required whilst delving deeper into a world they have great interest in. We aim to develop this further by expanding its adoption to the individual mobile App once this becomes available as we feel this will empower our students creating *more independent learners who are* able to then manage what they learn and when they learn it away from the college day".

Chris Jones, Academy Director, TBCCFA, Crawley, West Sussex

In addition, as part of the marketing for the business that was aligned to my further assessing in various FE type settings, I performed a roadshow of visits during early 2020 and late in 2020 when lockdown restrictions were eased at various settings. These were not entirely classroom based as used various settings from indoor multi use games areas (appendix 77.) to lecture rooms (appendix 78.), Stages (appendix 79.) and sports social club (appendix 80.). With students having a more hands on experience of the technology, by being able to look inside these device housings to see what each sensor is and what is involved, helping them to further grasp understanding surrounding wearable technology (appendix 81.).

These visits ranged from a more football focused type academy, one being West Bromwich Albion (WBA) foundation a mix of ITP type College day release and both male and female teams linked with WBA playing in the premier league (2020). The direct result of this was that the foundation purchased the system, demonstrating the value they saw in its inclusion and again further evidence of the entrepreneurial benefit of the professional doctorate. West Nottinghamshire College, whilst this was a college the lecturers and some of the students were involved with the local professional football academy of Mansfield Town Football Club. This again resulted in a sale to Mansfield Town Football Club for use with their under 18s fulltime students, similar type of programme to that at the SFF employed in the aforementioned study. The final example here being Sandwell College that also had links similar to West Nottinghamshire college as their relationship was with professional football clubs, these being WBA and another local football club Wolverhampton Wanderers. These relationships providing a pathway for students from FE to HE with the University of Wolverhampton. Whilst this did not result in a direct sale to date, I have been assisting the college in a large European funding bid in excess of £100,000GBP (appendix 82.) that would allow all their FE students access to the wearable technology system developed in study three that the business Quant-CX Ltd was now seeking to commercialise.

The senior lecturer at Sandwell college was a member of one of the sub focus groups, these consisting of members that were considered experts in the areas covered within the project and recruited during the snowball sampling techniques employed in study two and beyond. A series of One - One interviews were conducted and these concluded that in relation to the course delivery around sports coaching and development, that this system allowed for a more interactive teaching student experience. Additionally, increased engagement and that students were better able to relate to the outputs from wearable technology (appendix 83.), being further expanded on, in a further later One - One interview with the lecturer who commented that

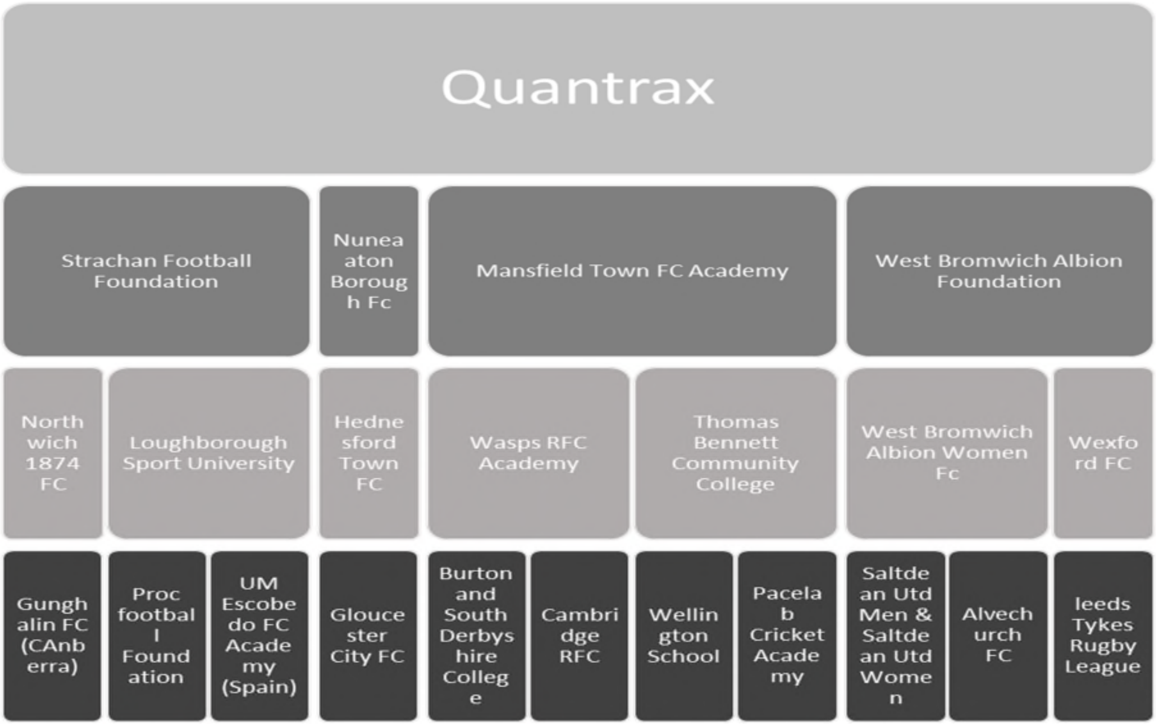
" we are seeing the practice inform the theory as opposed to the theory informing the practice that is better for students as they are learning from their own direct experience rather than out of a book"

James Moore Lecturer Sports performance and coaching Sandwell college

Student experience was seen as being better in their overall engagement and increasing understanding of the science involved (appendix 84.).

These commercial offerings and real-world impact are further evidence that the products and system developed within this project are filling the gap identified in the earlier studies, and that the product is fit for purpose for use in football related FE settings, with an additional benefit that it can be used across sports. To help illustrate this a concept map (Figure 55) evidence this, by illustrating the impact it is having when applied in the real world with live customers that are paying for the products and service provided that has been developed and launched by the created company Quant-CX Ltd, this product named Quantrax. Again being a play on words with the Quant meaning to quantify and the name of the company and the trax part meaning to track your movements hence the name Quantrax

Figure 55. concept map of customer traction



What (Figure 55) also illustrates, is how a snowball sampling type technique can be used in the market place. In total 22 customers had purchased the products these included amateur grass roots adult football club men and women (n=6), Academies that have education component (n=4), HE university (n=1) FE College (n=3), Semi Professional Football teams (n=3) Full time Professional football teams (n=1) ITPs (n=4)

7.6 Conclusion

It is apparent that the many moving components or elements involved in this study are changing and that these changes are moving exponentially, advances in technology, coach development, COVID-19, teaching methods, remote learning and teaching, even qualifications.

An example in qualifications during the timeline of this project has witnessed in FE the introduction of revamped BTEC suite of qualifications in 2019 and now in 2021, there is seen a new direction, with the promotion now and shift away from BTEC type courses, as funding is now being directed to the Governments new technical vocational qualifications (T-Levels) (Foster and Powell, 2019; Avis et al., 2021). These qualifications appear to be viewed by teaching staff as a blended learning approach of being a mix of classroom and real life work experience, or as lecturers interviewed put;

"On the job real life experience and learning"

Whilst the T-Levels are a new programme at level 3 it has been introduced to simplify a confusing and everchanging qualifications landscape along with promoting a technical education for increased employability (Foster and Powell, 2019). Lecturers feedback was that by employing wearable technology as in this study, better prepares students to advance into level 3 and beyond under this new qualifications framework (Education, 2020). Furthermore, rather than look to develop a new module for FE, this study demonstrates how a wearable technology solution such as that developed and employed in this study is able to accommodate and in fact enhance current modules without the need to construct yet another module within the suite of qualifications (Rogers and Spours, 2020). This being something that historically has happened resulting in overcomplicating and expanding an already congested suite of qualifications and modules within education (Straw et al., 2019). Furthermore, that mobile applications that have an involvement with stakeholders that would be directly employing it use is far more successful and accepted as in the case here with coaches and is supported in similar research (Evmenova et al., 2019).

It is apparent that by introducing wearable technology that moves away from being the domain of a specific member of staff such as a sport scientist, to ownership which is more student based, with the addition of being integrated into education as well as football performance has resulted in buy in from coaches. The results of this increased engagement with coaches does give me confidence that the system developed has far more benefits than just for current students using in this study.

Moving away from the silo type culture in ITPs and other FE type settings and more to an inclusive eco system type of setting, that is far more accessible and adaptable to accommodate many different uses and users. Furthermore, it has proven that it can enhance current and changing educational frameworks and integrate into modules rather than revert to what is usual in research that results it new modules being conceptualised and theoretical frameworks then adding a further module to an already congested qualifications body. That has been identified as such and resulted in government streamlining these by as mentioned earlier the implementation of T-Levels.

Study four has clearly demonstrated that academia and industry can work closely in unison together to solve real life problems that have been identified that fulfils the aims of a professional doctorate. Furthermore, that these solutions when introduced into real world situations not only cope with demands but are also able to flourish in an entrepreneurial way, that will encourage more such partnerships with Academic institutions such as universities and business such as SMEs described earlier in study three.

CHAPTER 8.

Critical Synthesis

8.1 Introduction

The following chapter will articulate the research and professional outcomes achieved as a result of the process of this professional doctorate. Results along with my interpretations will be described as a form of meta-reflection (Thorpe and Garside, 2017), which hopes to illustrate the theoretical, applied and conceptual elements of the journey. To commence with revisiting the original research and professional aims and objectives of the project.

8.2 Aims and Objectives.

8.2.1 Research aims and objectives

The overall aim of the research contained within the thesis was;

The primary aim of the project was to design and develop a wearable technology product that can be applied in a football specific FE *and* HE *environment.*

The aim was achieved by the investigations conducted in the four studies described within chapters four, five, six and seven

Being further detailed around each specific element that contributed and fulfilled the achievement are outlined further here in the following research objectives.

1. *To Identify the extent and type of and approach to the use of technology in football related education programmes in FE and HE settings*

Achievement of this first objective was described from the results of the survey conducted and described in chapter four. Wearable technology is being used and that use is increasing across Football, FE and HE settings and is predominantly reflective of that used in the football industry being GPS vest and Heart rate chest strap types. Within FE there are subcategories consisting of colleges, professional football academies and ITPs. These ITPs are made up of a variety of commercially operated business that include private academies. Private academies are often established by former professional players, not for profit foundations and charities, and national coverage companies. These FE settings provide a range of sport related qualifications (e.g., BTEC & SEPs) that include mainstream subject matter (e.g., Numeracy, Language, IT). Wearable technology is predominantly deployed and used in a similar manner to the senior professional game, that of performance purpose (84%) rather than educational (13%).

When used for education in an education setting of a college it is mainly for student learning experience rather than any specific subject and the measuring of its impact and usefulness is unknown. It is used more frequently in the football industry academy type settings, than in the education industry college and ITP type settings. Results and feedback from wearable technology where used, are communicated equally (openly and privately) raising concerns over GDPR, ethics and privacy. Results are predominantly displayed in Paper form or broadcast via large display screens, with the most popular location to display being inside changing room wall across all settings. Management and collection of data is performed mainly by sport scientist (football) & lecture (Education) with student and coach lower, within sport scientist posts this included a further breakdown that included studentship/interns. Findings also suggested that improvements to wearable technology were needed in, feedback and communication, understanding, simplifying, accessibility and making it more individualised.

2. *To describe and contrast the use of wearable technology in elite performance and football related* FE *and* HE *settings*

Achievement of this second objective was described in chapter five whereby a further survey identified a disjoint between coaching performance and coaching education uses and this extended further into other curriculum subjects. Identifying that for students to graduate from FE better equipped to advance to HE or direct employment, there needs to be an increased body of knowledge surrounding the uses and the capabilities of wearable technology used in football related FE settings. Moreover, that its use is not limited to just the sport department, but across the curriculum, Findings suggest that student engagement could be increased by employing mobile phone type technology, something that students relate to and most use on a daily basis. This could give simple relevant and immediate data and insights highlighting specific areas for improvement, that could increase the attainment levels academically and closer aligned vocational related experience. It also suggested that a system that better equips sport and education to collaborate rather than continue with the silo culture that exist needs to be devised, that would also when deployed allow for more individualised learning opportunities.

Additionally, It was identified that better education of coaches surrounding the uses of wearable technology, improved accessibility and better feedback and communication to all stakeholders was needed, and using mobile phones as the conduit could be a cost effective way to achieve. Finally, the research conducted identified the need to develop the potential for use beyond the confines of the classroom or structured sports activity within the FE setting, specifically given the changing landscape accelerated during the COVID-19 pandemic, with these changes being in both education and sport.

3. *Design and develop a wearable technology product and develop strategies to improve effectiveness of use of wearable technology in football related* FE *settings.*

Achievement of this third objective was demonstrated in chapter six, whereby the business component of the professional doctorate came to the forefront of the project. The solution being to build a new system comprising of a new wearable technology electronic device and related components such as, garment, software, web browser analysis platform and mobile applications. These were developed that would enable the project to progress to objective 4 and beyond. Armed with the findings from the previous studies conducted and detailed in chapter four and five, the focus group and an academic business relationship that was formed from my placement as part of the professional doctorate built the solution as described in chapter six.

This demonstrated that academia, industry and business can directly interact and influence each other and result in employment opportunities and advancement in chosen field. In addition, academia and industry collaborated effectively in promoting student entrepreneurial skills in business, which resulted in the wearable technology system developed that would allow for individual and group user separately and also interact, thus enabling for remote use.

4. *To propose, construct and disseminate an effective model in the use of wearable technology in football* FE *settings*

Achievement of this fourth objective was described in chapter seven, whereby the constructed system was deployed in a football related FE setting. Results reported that student engagement increased, and attainment improved. Additionally, it also demonstrated a more accessible and open platform for use in FE. By using the mobile application and cloud-based system that was constructed enabled cross pollination to other curriculum areas and promote individual ownership of learning beyond the confines of the classroom. The benefits went further than just students and found that coaches were becoming more engaged with the wearable technology and that they to were displaying independent learning thus demonstrating this can be used for coach education.

8.2.2 Professional aims and objectives

The overall aim of the professional practice contained within the thesis was

To forge a stronger bond between academia and business to help evolve a wearable technology solution to solve identified real world problems in industry and evidence in the overall project.

With the professional objectives being achieved by developing these throughout the thesis which supports one of the primary aims of a professional doctorate, that being business and academia working collaboratively to create better alignments with industry in solving real world problems, these objectives were as follows:

1. *Develop entrepreneurial skills –*

This was achieved by creating and developing a new business to support the project and exploit commercial opportunities. These are demonstrated in chapter six and seven, which clearly evidences that the system developed is a viable commercial product, that is able to fulfil market demands and have a positive impact in sport and education in a wider context than it was originally intended for. With ITPs, colleges, universities football and other sports subscribing to the commercial offering and this being sustained as well as expanding. Thus, evidencing that this solution is continuing to go beyond the project aim, as it further expands into the marketplace. To further demonstrate my entrepreneurial skills, I also conducted a presentation to industry (appendix 85.) to present a visual summary of the journey from an idea to a product. In terms of developing entrepreneurial skills, this presentation clearly evidenced that I have been able to exploit knowledge gained and created business opportunities, have a well-rounded understanding of the industry and able to share ideas. With experiencing failures and using these experiences as learning experiences and development opportunities.

2. *Improve and diversify modes of communication*
3. *Personal and interpersonal relationships*
4. *Task and Time management*

Objectives 2,3,4 were achieved by continuous development during the professional doctorate journey and are clearly signposted throughout this thesis, as I have continued to revisit with each chapter including a section "Professional Doctorate reflections, skills, practice and development". There are a couple of examples that illustrate these well in (appendix 86.) a presentation and interactive questions and answers session with the latest cohort of professional doctorate students about my experiences encountered during my journey. Additionally, this was not just to university level students as I had conducted presentations similar with FE colleges that also detailed the many transferrable skills gained over my career which this presentation was about (appendix 87.). Finally, the time and task management examples being the use of the project management tool and training diary within (appendix 2, 23.).

8.3 General discussion, future recommendations/direction

Design, Development and Implementation of Wearable Technology in Football in Higher and Further Education Settings in United Kingdom

The use of wearable technology, specifically surrounding its use relating to football, further and higher education has been discussed widely in chapter two. Its use to monitor physical activity has increased exponentially in recent years and has advanced to being the top fitness trend worldwide for the past three years. Furthermore, the 4th industrial revolution coupled with, increased exposure and availability, becoming more widespread has led to more companies providing various types of wearable technology to quench the unabated thirst for data. With these companies providing a vast array of metrics, reporting visualisations and modes of communication, is causing confusion and as science starts to catch up it is asking many questions on the use of wearable technology. Thus, highlighting the need to explore this through a series of linked studies as described within this thesis.

It does appear that sport specifically football has embraced its use, and this has expanded throughout the football landscape. This includes further and higher educational settings that also involve football, and this was supported in the investigation conducted and described in chapter four. It was also expanded on as it was found that within FE there are also subcategories the main being Colleges (290) professional football academies (72) and ITPs (900), unfortunately due to the competitive nature of this business sector, many ITPs are reluctant to share information, so it is not possible to determine exactly how many of these ITPs have football directly related to their setting.

A targeted survey with over 107 captures of relevant data concluded that all of the FE subcategories identified are, like football, increasing their use of wearable technology. It was further identified that they are also mirroring how the technology is being used in professional teams.

As described in chapter two, that it is used in football to help understand, quantify and improve performance of the players and team. Coupled with this rise in use, there is an increasing number of companies supplying the football industry with the technology. What is clear, is that this technology differs from company to company and has led to much confusion and a growing distrust between suppliers, coaches, sport scientists and even players themselves as the data the technology produces is getting miss communicated and lost in translation. Furthermore, that the technology is moving at such a fast rate that scientific rigour to validate is lagging behind, which further compounds the problems, especially with educational institutions requiring scientific support as part of the procurement process, especially with the high capital and operational expenditure that some require to purchase. However, when the data produced from the wearable technology is understood and communicated effectively, then it appears to be a most valuable tool in increasing performance in players and teams.

It was discussed in chapter four and five,

it appears that wearable technology is increasing in use in educational settings and that use is predominately reflective of that in the football industry. Being used to monitor and measure performance moreover than for educational purposes.

The findings of the first two studies as described in chapters four and five and the review of the literature in chapter two, further supported the aforementioned use and highlighted that when it comes to wearable technology that a disjoint exists, between coaching performance and coaching education uses. Furthermore, that this disjoint and lack of use outside of performance, extends further into other curriculum subjects. For students to graduate from FE and either advance to HE or direct employment, there needs to be an increased body of knowledge to gain a deeper understanding, surrounding the uses and the capabilities of wearable technology within football related FE settings.

The almost silo culture that exists between education and football, specifically education of coaches and students on coaching related courses. That there needs to be better communication and feedback mechanisms and with the added recent COVID-19 pandemic which has presented new challenges to the way sport and education are delivered and performed certainly questions if the current wearable technologies capabilities to accommodate as they were suitable in football for performance pre-pandemic.

Whilst it is recognised that current wearable technology is being used in education to give students an experience and in many cases that experience is into the use of what is being used in the football industry and how it is being used to measure performance, it was clear in chapter two that many within the football industry are questioning many aspects of the technology and the secrecy from commercially sensitive products and what is communicated is causing much confusion with practitioners in the field. Added to this confusion, an emerging misuse and lack of use as many practitioners questioning at best and many not using at all or not wanting to engage with using. Therefore, given these findings it was clear that a new solution would need to be developed. Not one to replace the plethora of products on the market that report on performance, but one that could overcome the challenges and barriers being faced in football related FE and HE settings. Furthermore, that any new solution developed needed to be capable to cross pollinate to other curriculum areas as well as increase student engagement, this would therefore compliment other subjects.

Student engagement by using mobile phones could give simple relevant and immediate data and insights and this was described in the study in interviews described in chapter five and in chapter two in the review of the literature, additionally it could empower students to become more independent learners, using a tool that they use daily in the mobile phone. In education there is also a need to understand better the basic components that are used within wearable technology with the sensors and how these are ever changing and developing amongst the many types used and why. In view of these findings, it was evident that a solution needed to be devised that would provide a solution and allow wearable technology to be an integral component within Football related FE and HE settings.

By employing an entrepreneurial approach that collaborate with academia and business chapter six describe the construction of a solution that would for all in sense and purpose be "fit for purpose" The forming of a focus group of industry experts help to guide the process in both a business and academia perspective the resulting overview of solution requirements was as follows

To create a wearable technology system that was affordable to more people than before, was similar to other products in the marketplace yet had unique features that filled a void that existed for accessibility, individualised, adaptable and simplifying to wider audience including those in further education and beyond".

This project at its core involved an iterative process to enable a workable solution to be employed successfully. In its most simplistic form, the basis of research is to

- Identify
- Construct a solution
- Evaluate the solution

By employing this approach chapter two three four and five describe the identification element and chapter six describes the construct of a solution and that one can be developed with academia and business collaboration. Chapter seven then was to evaluate in environments that the proposed solution would be for. It was clear from the study conducted within chapter seven that the solution constructed had made considerable advances in solving the challenges and barriers presented surrounding its use in FE settings in a real-world environment. Furthermore, that said solution could allow for individual ownership of learning beyond the confines of the classroom and college day. It had overcome one of the main barriers to use as it had eliminated the "black box" that was within wearable technology systems in use. There was within chapter seven description on how this can cross pollinate to other curriculum areas outside the sport performance focus including increased attainment in functional skills of numeracy and language with addition of ICT. These skills have continually been a focus of education and governments to find new ways of engaging students and advancing their learning to fulfil their potential.

Future research to investigate on a larger scale and longitudinally on all the benefits of employing an approach as that described here within this thesis may, however, be required. To look at what strategic benefits, not only in FE, but to the wider society including HE and industry.

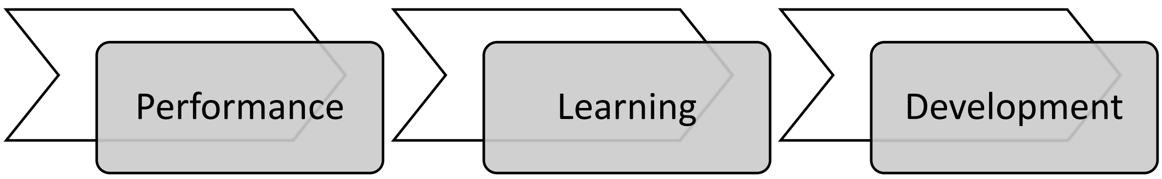
8.4 Meta reflections

The reflective process is nothing new to me as I have for many years used a paper diary to help me plan and reflect on my daily schedule, the one change has been that I have moved from using an A4 size to an A5 size diary. This is not that I have less to write, but I have learnt to be more concise on what I document being more of memory jolts that stimulates me to reflect and then document accordingly in either a formal or informal manner. Many may view that as perhaps antiquated and not in keeping with someone who is involved in technology. My thoughts are that not every person has to be the same and the way we reflect is like how we learn, it is individual and one that has to suit the individual over the masses. There in itself is perhaps one of the key areas of my development in understanding better that being individual is of benefit and can still lead to success however that is measured.

My professional development has improved which on first view some may say I'm stating the obvious. However, I wanted to highlight an area not identified in my self-audit and professional development and that is how I have now embraced the concept of learning from failures and to my changing career direction as the project has progressed. I do feel that this project has tied all my experiences, knowledge and skills together to enable me to be a more rounded professional.

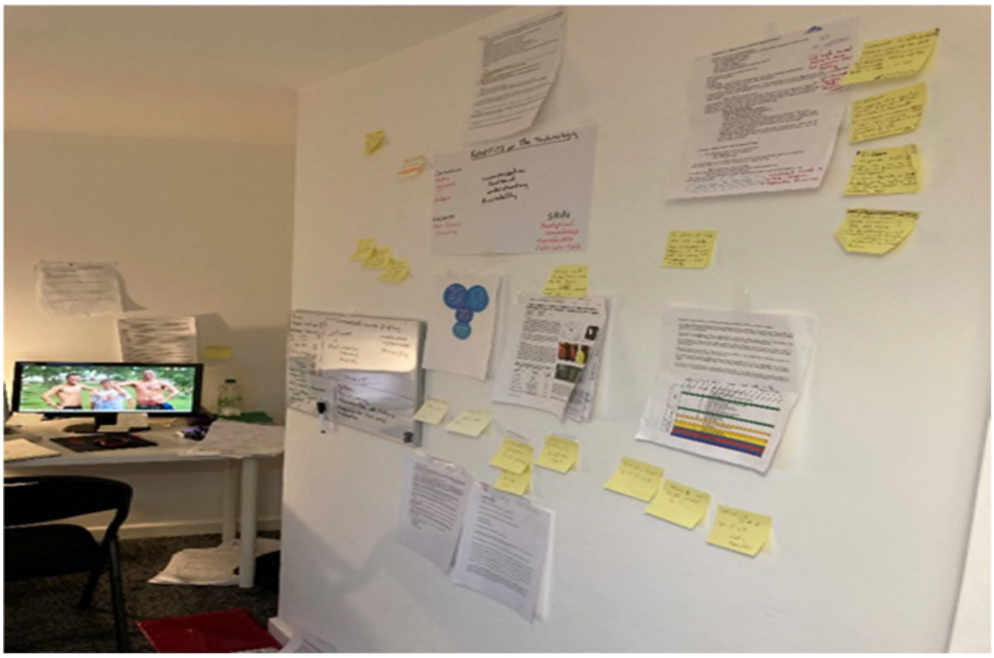
My process of change during this journey has been a move from a solely performance focused practitioner, that is best described as my comfort zone, to an education and developmental one. This has been more along a continuum (Figure 56), allowing me to move across and enable me to experience many views and given me a much broader body of knowledge and experiences.

Figure 56. My process of change during the professional doctorate journey



I think to help understand the commitment that I have given to this project (appendix 88.) illustrates well how as the project has developed and expanded so to has my workings, by moving home to have a dedicated room that enabled me to store and view my work was most valuable. Similarly, as previously described the benefit and use of maps to help me, constructing project maps (Figure 57) to allow me to plan review and reflect constantly has helped me greatly.

Figure 57. The professional Doctorate Project mapping in reality



In reading as part of my preparation for the professional doctorate to help understand the volume, structure and content, I recognise that mine is different as I have included a great deal of material that is not commonly used, certainly not to the extent I have used in this project. Most notably is perhaps the pictorial representations, movies and presentations, I do feel that these have given a better representation of the work and an more informed message rather than words alone. In terms of evidence of the work this is undisputable as the saying goes “the camera never lies” recording of this placement experience and reporting using visual representation in the form of photographic and video recording material, is something that is becoming more common in research (Miller, 2015), more specifically the likes of employing the mobile phone (Banks, 2018). These images can give a more precise meaning (Glaw et al., 2017) and better communicate (Margolis and Zunjarwad, 2018) the processes and various elements involved more fully than text alone (Ekanayake and Wishart, 2014). Evidencing, my developing diversity in communication skills, something that has been integral in forming and developing relationships across academia and industry.

In reviewing reflections from my professional doctorate journey, I believe that where I was more pragmatic in my approach to tasks, I have now become much more processed driven in approaches to tasks. That said, it is not that I have moved from one approach to another, but that I now consider both of these and evaluate which is the best approach. The reflective practice helps in this, as I am able to look back at what worked well and what didn't, and the approach used. Therefore, being able to repeat if a similar situation presents, and equally change to another approach if the last was unsuccessful "learning from failure". This learning from failure I spoke of earlier in this meta reflection, but this to me is perhaps one of the most successful outcomes of my professional doctorate journey and one that I have embraced. Furthermore, it has helped develop my entrepreneurial skills better and this has much empirical support within the literature (Ariño and De La Torre, 1998; Shepherd, 2004; Eskreis-Winkler and Fishbach, 2019). This reflective practice is described in more detail in charting the journey contained within the following chapter.

CHAPTER 9.

Professional Doctorate reflections, skills, practice and development

9.1 Charting the journey

Having entered HE relatively late in my career at the age of 40 and being the first in my family to gain a degree. I can remember the lack of opportunity to advance to HE when I was leaving school in the early 1980s. In fact the social background I came from meant that an apprenticeship being a very positive progression to increase employability prospects and career progression. HE was seen as being the domain of the elite and those that were fortunate to achieve grades allowing them to stay on at 6th form to then gain entry to a university. To become employable or progress any career an apprenticeship was therefore a compelling option, indeed, in many cases it was the only option. I was fortunate that the indentured apprenticeship I embarked on "Apprenticeship in Meat and Pork Butchery" was the official title. Did lead to fulltime employment post qualifying, which took some 5 years to achieve. Having spent then a further 5 years scaling the employment ladder until I left for a change of career, which by then had become an area manager for a chain of high street shops and an consultant to the industry. Much of this and my journey prior to commencing the current one are detailed in my professional background (Appendix 1.).

In the early stages of my professional doctorate journey, completion of a training plan consisting of a Self audit, Research proposal and Training plan contained within module one concluded with an action plan. Highlighting, being able to present to audiences related to my area of research would help improve my employability within these varying sectors and my professional practice. Dissemination of my literature review findings and early research plan to the AOC regional events enabled me to refine my presentation skills (appendix 4). I spent a total of 6 weeks preparing, presenting and reviewing feedback from these events that involved me having to travel extensively throughout England. Unfortunately, due to the Government restrictions coming into force in March 2020, prevented me from being able to present at the southern meeting and also Scotland. However, I was able to present and talk with on numerous *occasions through virtual meeting online, with the head of the southern region which they then conveyed to members of. At the latter part of the presentation one slide (appendix 4) invited attendees at all the events to participate in an activity to stimulate conversation and interest, as well as gaining further insight into the use of wearable technology in further educational environments (appendix 8.).The feedback from these gave me further background that I was able to put to good use in helping to construct the questionnaire for study one and also some background in preparation for the further studies in the project.*

These new relationships that I formed continue to develop and communication with the AOC national committee an ongoing process throughout the project and beyond, involving regular updates on my progress findings and direction. The AOC has a commercial wearable technology partner that sponsor the national Colleges football teams for both men and women teams and therefore any studies to be allowed that involve them and wearable technology need to be approved to ensure there are no professional conflicts. This is usual customary business practice in the UK in relationships such as these described (Kirkpatrick, Pederson and White, 2018), again with my previous experience both in football and in business I found I was able to draw on these to help me to continue with my development. Specifically in building relationships across the various industries and with multiple stakeholders, at this early stage of my professional doctorate journey and part of my overall project aims. The developing networking skills, resulted in my industry related contacts expanding and able to advance these as I progressed, which involve recruitment of experts from various settings. With FE setting being new to me, this was something that was an area of concern, it was therefore pleasing that it resulted in many positive outcomes. One being the recruitment of expert practitioners in the focus setting of FE. A highlighted developmental progression would be to build on these regional meetings to wider audiences including presenting at related industry events and *national events. Even with an uncertain climate with current restrictions, planning for in the future will help with my development as well as dissemination of my developing research.*

Identified in my self-audit and research plan (appendix 1.) was the need to develop the ability to better identify, collect, collate, critically analyse, synthesise, summarise, report and disseminate information that relates to my research area, and the first study went some way in developing all these. In addition, the first study started to evidence my expanding in different methods in research with the inclusion of free text answers providing a deeper understanding than from just quantitative data alone (Harper and McCunn, 2017). This involved more qualitative analysis that help me prepare for future studies specifically study two. Having conducted coding as part of this research and developing an understanding of the processes of analysis of text. My supervisory team being most valuable with this providing guidance and support as well as recommended reading (Saldaña, 2015). The increasing network of researchers helped in this in both reading material (Braun and Clarke, 2019) and sharing experiences from similar research methods. In addition, this is all helping to inform study two, thus developing a cyclical process and Action research (Drummond and Themessl-Huber, 2007; Dawson, 2012) as part of my overall project and in keeping with the professional doctorate process.

By adding this section further helped with my reflective practice, some examples of this being: Writing skills, by reading more peer reviewed literature, identifying that I am translating and communicating in written form with a much smoother flow. Proof reading, Enabling me to identify errors in previous work performed as part of module one. I identified that references were not inputted correctly and as such, undertook further training from Library services at LJMU on Endnote, amended module one and factored in time to further proofread all my work. By continually updating my training plan (appendix 2.) that I constructed in Excel to support my timekeeping, as well as provide an overview, something that is common in business when *managing projects with many developing and interlinking components (Nicholas and Steyn, 2008). Continually revisiting my literature review in cross referencing within discussion section in the studies as they were produced, as well as editing as part of a continuing review of literature including recently published material that is relevant to the project.*

Perhaps one of the largest advances is in my growing knowledge as a researcher, highlighted when reflecting on the second study. In the research proposal this study was intended and set up to be conducted employing an e-Delphi type approach. Whereas in reality it was adjusted and employed a snowball sampling technique as the study was better suited to this. My further readings and on-going research directed me towards this change and I feel that it is important to recognise this as a key component of my developing professional practice and growing maturity and confidence adapt my approaches accordingly. This also reminded me of a prayer that my father has commented to me throughout my life and does put this into context as follows:

"God grant me the serenity to accept the things I cannot change, the courage to change the things I can, and the wisdom to know the difference"

Further reflections highlighted, that It appears that many organisations are spending so much time and money in an unending thirst for something new, quirky, different, and continually searching for new methods to educate (you only have to look at the vast number of qualifications continually increasing). Sometimes missing out on everyday items to hand, the solution could be presented by better use of what we have at our disposal. Specifically, the Smart phone as aforementioned in the review of the literature, a device that is now like other types of wearable technology in that it is advancing at an accelerated rate, is increasing in use, and now common place. This reminded me of a couple of quotes that I heard and led me to embark on investigating the uses of mobile technology in sport and if a mobile phone could be used in a similar way to other technology being used in football (Tierney and Clarke, 2019).

The first from Inga Beale CEO of Lloyds of London "For many people, the smartphone is the first and only computer they have" and Professor Klaus Shwab of the World economic forum who said " there has never been a time of greater promise or greater peril" This was in reference to the fourth industrial revolution (Bomberg, Romanska-Zapala and Yarbrough, 2020) as described earlier in chapter two, my review of the literature. Furthermore, in my experience specifically with technology, like many fathers, I have spent many hours trying to Figure out the latest software update and features incorporated within my smartphone to then have one of my sons demonstrate to me as if it was so easy anyone could do it. An example of the capabilities in these devices continues to amaze me, the number of occasions I have searched for an answer to a problem to then have someone say those words "just ask Google" and now we have SIRI (Apple Inc). Interestingly when writing this chapter, I performed a google search to conduct some background reading on SIRI, this resulted in over 62,000,000 results which illustrates the vast array of possible answers. This throws up a positive in that I was able to improve my understanding, but then negative in that there were so many options. On what would have been one of the early technology pioneers, Alan Turing birthday (23rd June 1912), it does make me wonder as I am sat writing this chapter if he imagined we would be where we are today? With the vast majority of people now using a mobile computer as part of our everyday lives, but so many not exploiting all the capabilities within these devices.

In researching the background of a professional doctorate there are studies that I drew comparisons from my early career as a butcher apprentice (Jones, 2018). This further helped me to understand better the transferable skills and knowledge and how different aspects of and experiences encountered throughout my life, can be used to help me further develop. A more informal reflective practice, but one that contributes heavily to an holistic reflective practice. In respect to the developing project and inclusion of a project management board (Murphy and Ledwith, 2007), as well as upskilling and personal development, it was clear on the importance *of gaining knowledge and understanding of all aspects of a project (Loufrani-Fedida and Missonier, 2015). Specifically, those that involve innovative new products in electronics and technology and based in SMEs like the one described within the thesis (Yap and Souder, 1994; Loufrani-Fedida and Missonier, 2015).*

The reflective practice highlighted concerns surrounding privacy and security, being addressed as part of the project and detailed within chapter 6. It did present though, perhaps another potential solution to a problem in HE and FE, that of attendance including location, time and activity of students enrolled at the setting at. Having this ability for FE and HE settings to be able to monitor students could have many benefits and therefore should be investigated further. It is perhaps something that Academia and Industry may look to investigate at a later stage post this current research project. With this being an industry placement component of the professional doctorate there also required formal reflecting reporting in the form of a case study questionnaire, this was used to help evaluate the European commission grant awarding impact of which this project received via a company application for an Innovation grant (appendix 58.). This further evidences the importance of reflective practice as an ongoing process not just in academia as employed here in an live industry setting as part of the professional practice (Fulton et al., 2012).

Research skills

This study has certainly highlighted the professional doctorate experience in contrast to a more traditional PhD, it has been one that has involved me developing both a research as well as a business plan that are intrinsically linked and a much-needed requirement with any such collaboration that involves industry and academia, specifically when an entrepreneurial business such as the one for this project is the partner. What I found most appealing was in the searching to improve my theoretical as well as subject knowledge had a direct impact on my *advancing through the project as a student placement as this was being applied to the business environment. In applying for grant funding from Government agencies is never an easy process and is often littered with failed applications during the process. However, by utilising the ever growing skills from my academic research specifically in the increasing my theoretical and subject knowledge led to successful funding bids. Argument construction, Insight and analysing of relevant literature as well as the applied working all contributed, as well as improving my critical thinking and use of language to an ever-increasing number of stakeholders in preparing and submitting applications such as European innovation fund.*

A further self-development is that of my appreciation on knowledge gained through the diverse learning experiences with many of these unstructured and as in the current study perhaps unforeseen and were gained through external factors such as suppliers businesses failing and the plastic enclosure over moulding process failure. I feel that no amount of theoretical research can better equip me for continued career progression than that of these applied experiences. It is more learning from the failure of these and gaining from that experience to ensure that it better prepares me in the future. Certainly, there is support for this type of learning (Bolinger and Brown, 2014) and in a student context (Bolinger and Brown, 2015) that has been shown to gain a deeper understanding of knowledge gained. It was perhaps the failing of the first electronics supplier that a rethink of the whole project was contemplated. It was at this time that the value of the supervisory team and one of the focus group mentors came to the front, Neil Clarke from Coventry University has been with me throughout this journey and before for a number of years.With his and Professor Barry Drust's inputs, they helped me to turn this more into an opportunity to learn from. Whilst there was the financial as well as logistical issues of both of these examples and both being different, yet there were many similar characteristics such as both these were reliant on a fragile supply chain. Therefore, the learning experience was to better manage, and source elements required assessing the cost *benefit to each. Barry and Neil both helped me to embrace this rather than dismiss or ignore this as an opportunity and accept both the negative as well as the positive benefits of experiencing a failure.*

Having the professional doctorate embrace an entrepreneurial type business, has I believe, been of most value, whilst there are risks as highlighted with SMEs there is also a great potential to benefit. The very word entrepreneurship historically associated with being creative, uncertainty and risk, creating and exploiting opportunity (Long, 1983; McMullen, Plummer and Acs, 2007). This has allowed for more freedom in direction of the project than would be allowed if part of a much larger company or business and whilst the risks and benefits have been identified, it is important to remember that the failures that have presented have helped me as part of my reflective practice to develop my skills and knowledge by learning from these experiences.

An additional communication strand I want to highlight is in business introductions and first impressions, these can be the make or break of a deal. Therefore, in addition to creating a logo for the company and brand (Figure 46), there also required a business card (Figure 46). To be created to hand to people at meetings with my contact details on which is customary practice in industry. Additionally, branded sports clothing was produced for me to wear when performing any company duties involved in this project, this all helping to project an image portraying a professional business.

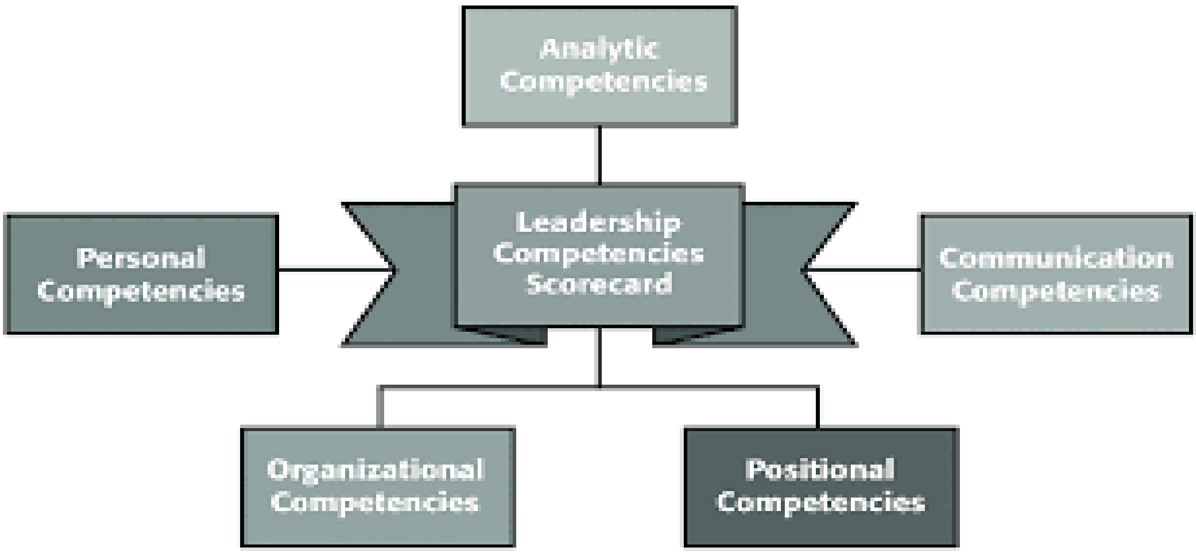
Figure 46. Quantrax Business card and development of company brand with logo designs

Task and time management

This has very much been a task orientated study as it has involved many tasks that have in parts run parallel to each other. Industry process is very much one of completing various tasks in an arranged order or flow and is also time restricted mainly due to the financial cost to businesses if time on task repeatedly runs over. Time and task management were two areas highlighted in my self audit (appendix 1.) as areas that required improvement and these have improved as my journey has progressed. Indeed, by being involved in the day to day of the business world and employing tools such as the project management board that these two are intertwined with each other. An additional task was to create and periodically revise a timeline tree for the business to help illustrate where the project was and how the various components were progressing (appendix 29.).

An area I want to focus on here is that of overall management, especially in relation to communication and working with others. Here I feel I have now developed a more leadership approach as opposed to a management one and this is reflected in a change in my personality that has developed from my wider reading and engagement with different individuals in *different settings outside of those which I was accustomed to. An almost opening of my eyes more to the wider world or bigger picture rather than a series of individual almost micromanaged tasks as my approach was before. Much of my reading that has informed my direction to this approach has presented from conceptual frameworks and models in the literature with one that I have employed to help develop my competencies illustrated in (Figure 47) ((Ruben, 2019). This has certainly helped with my communication skills as messages increasingly broadcast more clearly with consistency (Alldredge and Nilan, 2000) a key factor required in business such as these that have many elements and a diverse demographic (Guillaume et al., 2017).*

Figure 47. Leadership competency framework overview 5 key areas



This move from management to leadership is one that is being adopted throughout many organisations that are demonstrating increased productivity and success (Hargis, Watt and Piotrowski, 2011) and an area that I view as being ideal for this project from the collaboration of industry and academia. It is a further expansion of my BASES competency framework employed at the onset of this project and I feel that this further evidences my evolving role which I am currently applying this to.

I very much feel that I have matured in all areas and continue to develop those highlighted in my self-audit. Seeking of information and the management of information are areas that were identified early on in my development, the following example of supplementary information required in industry and business evidence how I am expanding in these areas.

The service and supports commitments document (appendix 62.), was an additional document produced and made available, as this was felt needed to assure the ITP of the integrity as well as compliance with government legislation and evidencing appropriate levels of security and GDPR compliance. This further expands on the growing issues around GDPR and security, non-more so than in the current climate of more use in technology due to COVID-19 and changes to working practices in the education industry.

This perhaps, is something that would not normally be required when employing an existing wearable technology that has been historically used in FE type settings. These would have set a precedence and have stable and mature set structures that have gone past the development stage, although they would still have a privacy and GDPR policy as like all products in this area. Indeed, the current project also has this as part of the business developed and is detailed further in study three contained within chapter 6.

This has also helped me to develop further my desire to continue to increase my theoretical knowledge with factors that lay on the periphery of the subject area but can impact positively and negatively if the knowledge is not fully understood in the context of the subject area. Something I feel is often overlooked specifically in qualitative research such as that I have and continue to develop. The reflective practice process has become increasingly integrated within my everyday practice and I find that it is most valuable in helping me to learn from daily experiences in a fast-flowing environment, that helps inform my decision-making process and direction.

CHAPTER 10.

Epilogue

10.1 Industry & Business created

Perhaps one of the most fruitful engagements from the LinkedIn post that was earlier described in chapter six. One viewer of the post was in fact the CEO of a company operating in the team sports market that focused on “grass roots” Football, Rugby, Hockey and Cricket, contacted me to investigate more about the product I displayed within the post and how it was developing. This relationship grew and progressed over the subsequent six months concluding in March 2021 with this company named Pitchero Ltd (Leeds, UK) purchasing the start-up company Quant-CX Ltd that was set up in 2018 prior to the commencement of the project.

Those six months from first enquiry to eventual purchase and takeover was seemingly a lengthy period. However, normal business practice is to perform a period of due diligence whereby a thorough investigation and evaluation are conducted to determine if a purchase should proceed or not. I could indeed have included all of this as part of my business experience, but this alone involved compiling over 200 documents and employing a team of legal experts to go over every single aspect of the business and an overview of this is described further in (appendix 91.).

This company had far more scope and capability to scale the company and product to meet the demands of the marketplace. This they are preparing for with a launch scheduled for mid to late summer of 2021 to coincide with the majority of the aforementioned sports normal preseason (July-September) and prior to the new academic year (September-October). All of this is changeable with the current COVID-19 pandemic still causing much uncertainty in the world.

A further benefit was that it has also led to my direct employment with this company and employ me as an advisor, consultant, come brand ambassador and on my first day was introduced to the company including all of the workforce and the CEO outlined the proposed launch of the new offering (appendix 89.). One of my first tasks was to help to produce a sales brochure for use by the marketing team (appendix 90.).

An ongoing task now is the testing for FIFA and IRB certification that was conducted in study three that resulted in failure. Described previously, this is required for the business to then be able to expand its commercial offering into the market place, specifically in competitive leagues and competitions as part of FIFA regulations that require products to comply with industry standards, also detailed in study three. Once products are approved then they are able to display either or both the football International match standards (IMS) and international Rugby Board (IRB) logo on their products and any promotional material. This is a key factor for companies in selling and promoting a product and a key consideration when a consumer is considering purchasing for assurance that the product is suitable for purpose being used and meets a level of standard for use. However, it is expensive in terms of an expense for a start up company that was Quant-CX Ltd, having failed the process once the outlay of a further circa £10,000 GBP was beyond the resources of the company. This not being the case of the established company that had took over the business and therefore able to fund a further application, it should be noted that failure of products such as this is not uncommon in industry and therefore it is not isolated to this project indeed this can be as high as 40% (Castellion and Markham, 2013). Therefore, the sale of a start-up business such as this, is an achievement in itself and the scientific underpinning and approaches employed during this project undoubtedly contributed to its successful completion.

There will undoubtably be some that will say that I should of kept ownership of the business that I built, but I would argue that I had taken the business as far as it was able to go with the resources I had and was not inclined to expand the business and venture into new domains and workings having not the desire to progress with that. There is a risk benefit that has to be evaluated and the risk was considered too great for any additional potential benefits. By conducting due diligence which is common practice in any takeover I discovered that business is very much that (business) and whilst I have viewed at times that it is like nurturing a child or breeding a new flower or helping to develop a player in football (all of which I have had success in), there does come a point where you have to allow for further growth and development that mean that your role changes. So, whilst I have sold the business, I am still very much involved in its future development and growth as I am a part of that by being employed by the company that purchased my business. Furthermore, I have come to the conclusion that my strength are more in the concept and initial development stages of a business and once the business has reached a state of maturity and stability that it is then time to move on to the next project. Very much an entrepreneurial outlook and one that I am looking forward to the next challenge presented.

This next challenge already looks to be emerging, all be it very much at an embryonic stage, I have now set up a new company "JKN Advisory Ltd" the JKN being the initials of my three sons. This company will enable me to continue along this journey with much of what I have done in the professional doctorate being expanded on, the focus being education and sport using wearable technology. I have delivered a presentation to various potential partners and looking to progress this to the delivery stages later in year (appendix 92.).

10.2 Academic research

In terms of academic research, I am firmly of the belief that continued collaborations with industry and academia will lead to more rather than less or diluted academic research. This belief is evidenced from my involvement in the professional doctorate and how its growth and promotion from more sectors accompanied by the changes in the world following the global pandemic of COVID-19, will in fact not only see changes to education and academic structures but will see academic research being more relevant to the wider society. Science for one has grown exponentially due to the increased exposure as society thirsts for knowledge increases.

10.3 Final thoughts…

The professional doctorate journey has been long and hard, and there were times when I questioned whether it was worth all the hard work and the toil. Now I have completed this project the answer is emphatically "yes" but ironically, I don't see this as the "end". The professional doctorate process has provided me with the confidence to pursue further journeys, and although I am unsure of the next destination, I have the confidence that I have the skills to navigate the challenges that lie on the road ahead.

CHAPTER 11.

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Appendices

Appendix number	Name of document	Type of document
1	Self-Audit and Research plan	Word
2	Training diary	Excel
3	Study 1 poster advert	Word
4	AOC regional presentation about my research	powerpoint
5	Participant information sheet	PDF
6	Survey Questionnaire study 1	PDF
7	AOC 3 slides for distribution to all local meetings within regions	PDF
8	Feedback from Regional event Task postits	PDF
9	Study 2 part 1 online questionnaire	PDF
10	Study 2 part 2 Expert questionnaire	Word
11	Study 2 expert criteria for recruitment	Excel
12	Study 2 setting background information	Word
13	study 2 part 2 participant information sheet	Word
14	study 3 focus group	Word
15	Quant Business plan presentation Road map	PDF
16	Linkedin profile	png
17	Linkedin post	png
18	Comparison and MVP (Minimum Viable product)	Excel
19	CUE Publication (Coventry university enterprise)	Publisher
20	Leisure football walking football	powerpoint
21	leisure leagues back-end reports from trials	powerpoint
22	POC trials leisure industry Summary director’s presentation	mp4
23	study 3 trello project management boards	Word
24	Trial case study of use in commercial enterprise	powerpoint
25	MSDS (material safety data sheet	PDF
26	Distributor Positioning Road map extended presentation	PDF
27	Conference presentation GNSS Downstream Markets	PDF
28	pick and place components v3 prototype	MOV
29	Timeline tree Sept 2019 v1	PDF
30	ce certification EU Declaration of Conformity Quant-CX Ltd sports tracker Va1	PDF
31	Rugby specifications document test protocols	PDF
32	FIFA test-manual-epts-wearables-v1_6 (1)	PDF
33	garment design	MOV
34	APP screen flow 1 proof of concept	powerpoint
35	How to Download and upload your data from your unit using IOS 2020_09_24	Word
36	IOS App trouble shooting guide	powerpoint
37	functional requirements inc speed zones and tab flow and Data transfer packets	Word
38	user sign up registration screen flow	Word
39	How to Download and upload your data from your unit using IOS 2020_09_15	PDF

40	testing connection on user interface mobile application	MOV
41	Team App data download	mp4
42	Team coach user manual Webbrowser	PDF
43	testing user interface to sync	MOV
44	android application user login	mp4
45	how to use guide 1. using your unit	PDF
46	How to use	M4V
47	Trouble shooting guide. APP. device . WebAnalytics	PDF
48	Session report	PDF
49	single player report	PDF
50	single player report	Excel
51	session Excel export report	Excel
52	single player report in a team report	PDF
53	Raw timestamped data CSV file	zip
54	Team Coach user manual	PDF
55	Cookies policy	PDF
55	Privacy policy	PDF
55	Warranty	PDF
55	Terms and Conditions	PDF
56	in house testing	Excel
57	Research team shuttle test_2020_09_02 expanded metrics)	Excel
57	shuttle testing heat map and GPS speed chart for Walk and run	Word
57	Shuttle testing in the field various levels of user	mp4
57	Research team shuttle test Basic numbers 2020_09_02 FULL PRODUCTION UNITS	Excel
57	shuttle test_2020-09-02	PDF
58	CUE Case Study Questionnaire	Word
59	Applied pilot study assessment	Word
60	Applied pilot study SFF proposal presentation	powerpoint
61	SLA Strachan Football Foundation.2020_07_24	Word
62	service and support commitments with further insight and details including certifications and Data management.	Word
63	pre assessment SFF pilot study Questionnaire participant information	PDF
64	orientation day timeline	Word
65	SFF lecture 1 intro to wearable technology in football	powerpoint
66	Viewing your Data on your mobile phone	powerpoint
67	SFF match data	Excel
67	SFF match PDF team report	PDF
68	testing in field single users	MOV
69	students viewing data	MOV
70	Coaches interacting with students data	MOV
71	Student task transferring from field to classroom link to curriculum	mp4
71	Student task transferring from field to classroom link to Curriculum	PDF
72	Zoom analysis of lecturer platform experience contextualising speed zones	mp4
73	student feedback from use One - One	MOV
74	Lecturer Follow Up post pilot complete transcript	Word
75	Template for coaches. TMC &RTP master book updated 2020_08_11	rar

76	Non league football use	jpeg
77	WBA presentation to students (2)	MOV
77	WBA presentation to students	MOV
78	HE lecture	jpg
79	Presentation set on stage	jpg
80	sports social club presentation	jpg
81	FE students hands on with technology	jpg
81	FE students	jpg
82	EdTech - New Assessment Methodology Spec - 081120	PDF
83	Students relating to the data lecturer views	MOV
84	practice to theory of technology in practice	MOV
85	The journey in the applied settings Building the solution	powerpoint
86	The researching Professional My Prof Doc journey	powerpoint
87	A career in sport science me living the dream presentation to colleges	powerpoint
88	My Home working set up during my prof doc and in the current climate	Word
89	intro to staff on GPS	powerpoint
90	PitcheroGPS - Elite & Academy Football Brochure 2021 V1.2	PDF
91	Pitchero - Quantrax Company Information Request	Word
92	Kurdistan offering	powerpoint