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Physical literacy: impact and cost effectiveness in primary school settings.

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Physical Literacy – Impact and Cost Effectiveness in Primary School Settings

By David J Kidd

June 2021

A thesis submitted in partial fulfilment of the requirements of the Robert Gordon University for the degree of Master of Research.

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List of Abbreviations

AA	**Academic Attainment**
BMI	**Body Mass Index**
CAPL	**Canadian Assessment of Physical Literacy**
CfE	**Curriculum for Excellence**
CG	**Control Group**
ICER	**Incremental Cost Effectiveness Ratio**
IG	**Intervention Group**
PL	**Physical Literacy**
RCT	**Randomized Control Trial**
SIMD	**Scottish Index of Multiple Deprivation**

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Abstract

David Kidd, MRes. Physical Literacy – Impact and Cost Effectiveness in Primary School Settings

Physical activity and academic attainment of children are internationally regarded as some of the most significant areas of public concern and interest (World Health Organisation, 2010; Scottish Government, 2018). There are a range of interventions discussed in literature seeking to enhance both outcomes, as well as a growing body of literature regarding the ability of enhanced physical activity to improve the attainment and development of children. There is a growing demand for cost effectiveness analysis within the field, and investigation into the role digital technology can play in maximising adaptability and accessibility. Physical literacy is an emerging concept focussed on the motivation and ability to value, and participate in, physical activity throughout the lifecycle (Whitehead, 2013). The aim of this research was to investigate the influence of a physical literacy intervention delivered using digital technology in Scottish primary school settings on the academic attainment of children, as well as to estimate its cost effectiveness.

A control trial methodology was implemented in which 13 participants were convenience sampled from the STEP Programme. STEP is a physical literacy intervention delivered twice daily by teaching assistants using a digital platform in a one-to-one environment, in which pupils' complete exercises specific to their physical competencies as assessed by the teaching assistants. Pupils completed these sessions for one full academic year, with academic attainment data collected at baseline and after the end of the year carrying out the intervention. Teachers also assessed pupils via a pupil questionnaire covering a range of academic and developmental areas at these time points. Changes in these were compared to the group themselves as well as to 64 pupils of a comparable age, stage, and ability in a control group, who received traditional education over a comparable timeline. In order to assess the effect of the intervention on Academic Attainment, a binary logistic regression analysis was carried out, while the pupil questionnaire changes were evaluated using a T-test. Cost effectiveness was calculated first by implementing the ingredients method to establish all components of the intervention, before costs were then associated and used in accordance with the effect sizes, producing incremental cost effectiveness ratios.

Results of the binary logistic regression suggest that the STEP intervention was able to significantly ($p \leq 0.05$) impact on pupils writing, listening and talking, and health and wellbeing attainment relative to the curriculum for excellence. Moreover, when evaluating the pupil questionnaire analysis, results suggested that STEP was able to significantly improve pupils reading and mathematics competencies, as well as several important behavioural and developmental attributes. When compared to other interventions in published research, cost effectiveness analysis suggests that for literacy attainment, STEP may be a preferable option that provides high-cost effectiveness, however this must be interpreted with caution given the relatively low sample size.

Key Words: Physical Literacy, Academic Attainment, Physical Activity, School Attainment, Educational Research

1. **Introduction**

Physical activity, which is defined as "bodily movement that is produced by the contraction of skeletal muscle and that substantially increases energy expenditure" (US Department of Health and Human Services 1996), has been identified as having a major impact on physical health, mental health and wellbeing, and body composition of people of all ages (Miles, 2007). Physical inactivity is internationally regarded as one of the most significant public health concerns of the modern era (World Health Organisation, 2010; Scottish Government, 2018). In addition to being one of the leading five causes of mortality across the world, physical inactivity is also a primary symptom of several physiological and mental disorders such as hypertension, diabetes, heart disease and depression (NHS Scotland, 2019; World Health Organisation, 2010; Lee et al., 2012; Ekelund et al., 2016; Schuch et al., 2017). Furthermore, there is a significant financial burden caused by the extent of the physical inactivity issue, with studies completed in recent years claiming the cost to the UK healthcare system is as much as £1.3 billion annually (Ding et al., 2016). This figure rises when considering the wider impact on UK society to £1.6 billion, and further still to £43 billion when assessing the impact of physical inactivity globally (Davis et al., 2014; Pratt et al., 2014).

Amongst children and young people, a comparable gap between those achieving physical activity guideline levels and not exists between those aged 5-15 in both Scotland and England, as indicated by figure 1.1 (Scottish Government, 2017; NHS Digital, 2018). As can be seen in both countries less than half of 5-7-year-olds are identified as meeting the recommendation of 60 minutes of moderate-vigorous physical activity per day (Department of Health and Social Care, 2011), with this value dropping further still to 12-18% by age 13-15. However, despite having over 1,600 children surveyed in the Scottish study, and 1,985 children in the Department for Health report, the accuracy of these data must be questioned as a result of the use of self-reporting measures (Smith et al., 2017), particularly when considering the suggestion in a series of systematic reviews that self-reporting questionnaires conducted with children demonstrate poor validity and repeatability when seeking to establish physical activity status (Kohl, Futton and Caspersen, 2000; Lubans et al., 2011; Helmerhorst et al., 2012). Moreover, the validity of these studies is limited by their failure to account for activity carried out during the school day. Considering the recommendation for schools to provide a minimum of 2-hours activity per week for children, and the variety of sources that children are reported to gain their activity from, this omission is likely to have led researchers to portray a falsely low level of children's activity (Scottish Government, 2019; Department of Education, 2014; Sallis et al., 1991; Sallis and Saelens, 2000; Sirard and Pate, 2001). Despite these limitations, however, the findings above are similar to those across other developed countries (Riddoch et al., 2004; Fakhouri et al., 2013; Nader et al., 2008) and indicate a need to better understand the reasons for this limited participation in physical activity and its underlying consequences.

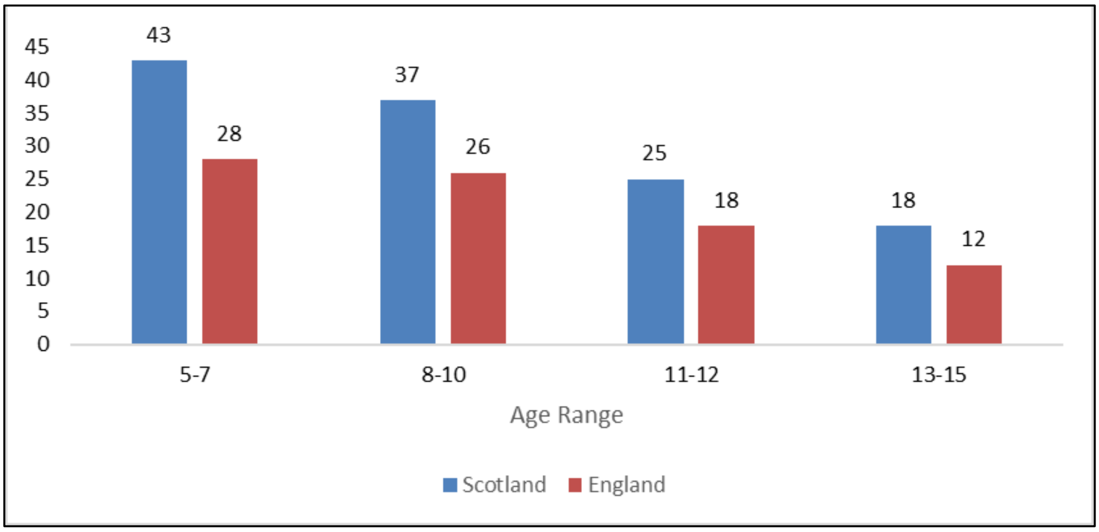

Figure 1.1 – Percentage of Children in Scotland and England meeting physical activity guidelines. Adapted from Scottish Government (2017) and NHS Digital (2018).

Several factors are proposed to influence the volume of physical activity attained by children and young people. One prominent factor proposed in recent years is the advance in technology, with screen time increasing dramatically at the expense of physical activity (Bucksch et al., 2016; Caulfield, 2015; LeBlanc and Chaput, 2017). Another factor proposed to influence physical activity rates in children is the extent to which their family adopt and appreciate the value of a physically active lifestyle (Wang et al., 2015). It is proposed that children with physically active parents will themselves be more active (Chiarlitti and Kolen, 2017; Brzek et al., 2018; Solomon-Moore et al., 2018), which is evidenced by Garriguet, Colley and Bushnik (2017), who identified moderate relationships ($r=0.44$; $p=0.0012$) between the screen time and moderate-vigorous physical activity of children and their guardians, as well as the number of steps they take ($r=0.31$; $p=0.00001$). This agrees with research on children of a comparable age across the world (Xu, Wen and Rissel, 2015; Van Der Horst et al., 2017; Tu, Watts and Masse, 2015) and indicates that to maximise effectiveness of a physical activity intervention for children it should seek the support and involvement of the child's immediate support structure.

Much like the rates of physical activity throughout the country, academic attainment (AA) of children is an area of significant public interest (Sektnan et al., 2010) and resultingly the Sottish Government publish annual reviews by the Scottish learning directorate (Scottish Government, 2018). Within these, the challenges facing learners are evaluated alongside the rates at which pupils are obtaining the expected attainment levels relative to their age. Within Scotland pupils are assessed on a framework known as, "Curriculum for Excellence," (CfE; Scottish Government, 2008), dividing their journey through education into 5 levels of attainment as shown in figure 1.2.

CfE Level	Stage	Age
Early	Pre School Years	2-4
First	To the end of Primary 4	5-8
Second	To the end of Primary 7	9-11
Third and Fourth	Secondary 1-3	12-15
Senior	Secondary 4-6/College	16+

Figure 1.2 - Education Structure for Scotland (Scottish Government, 2018) CfE – Curriculum for Excellence.

It is a key characteristic of the Scottish Educational framework that the decision regarding when (and if) pupils have attained the level they are currently working at is determined using a teacher-opinion system (Scottish Government, 2018). This differs from the English system where formal assessments are included at the end of each stage to determine if a level has been passed (Department of Education, 2018). This formal assessment system has been proposed to have limited effectiveness as students need only learn what is necessary to sit a test without any need for the retention of information (Harlen et al., 2002). Gardner and colleagues (2011) suggest that this style of learning and assessment contradict the principles for optimal assessment by limiting the extent to which pupils will be motivated to learn content in a sustainable manner. Moreover, it is suggested that the recognition of individual success, irrespective of how this relates to normative or expected values (as is more achievable in teacher-opinion assessment (Harlen et al., 2002)) leads to improved long-term attainment. However, the variance and heightened potential for bias in teachers' perceptions of competency can lead to varied and unreliable findings in teacher-based assessment, potentially limiting the validity and reliability of research into school attainment lasting longer than one academic year, or in which the research crosses over more than one assessor.

It is a trend in Scottish education that the number of pupils attaining the expected level falls as children progress in age, as illustrated in figure 1.4. The main reason proposed in literature for this decline in attainment as children grow older is that societal inequalities progressively widen the gap between the most disadvantaged pupils and others their own age (Demmler et al., 2017). This position is further supported by the evidence illustrated in figure 1.3 below using the Scottish Index of Multiple Deprivation (SIMD) categories.

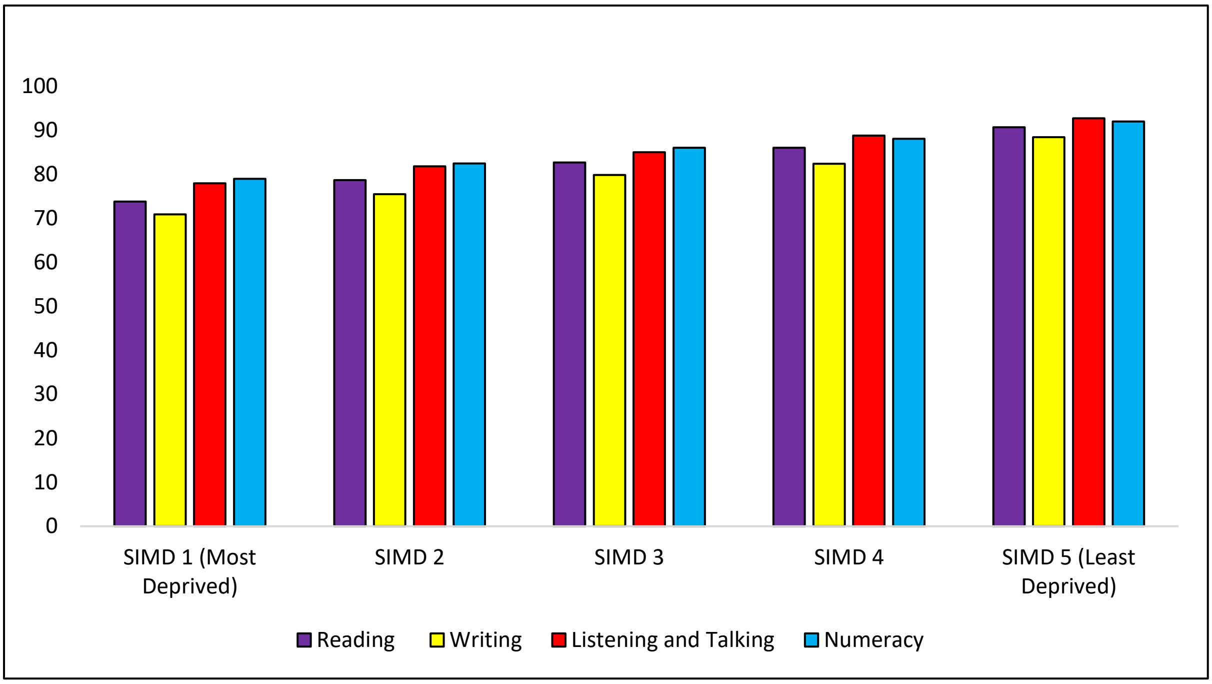

Figure 1.3 - Percentage (%) of Pupils Attaining Expected Curriculum for Excellence Levels by Subject Area

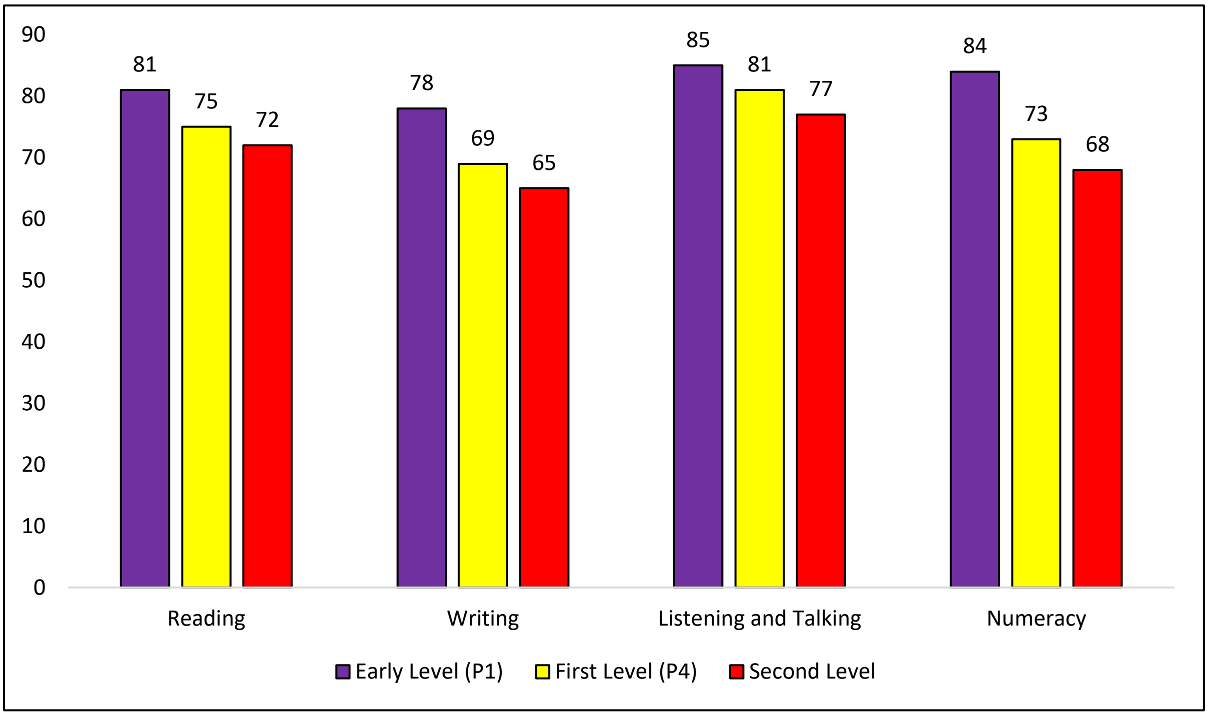

Figure 1.4 – Attainment of Expected CfE Level by Age 2017/2018

According to research (Demmler et al., 2017; Pati et al., 2011; Boxer et al., 2011), failure to reach expected academic attainment throughout first level has wide reaching consequences. Moreover, children who start well academically and then fall behind their classmates in the early stages of education are more likely to perform poorly in senior education, as discussed in review by Howieson and Ianelli (2008) who conducted a comprehensive analysis of the Scottish Schools Leavers Survey from the 1994 cohort of pupils. In addition, formative academic performance has been suggested to impact on the prevalence of health risk behaviours by Abbott-Chapman et al. (2011), specifically identifying alcohol abuse, smoking and sedentary behaviour prevalence as higher in poor attaining children aged 7-15 in 1985 surveyed again between 2004 and 2006.

This is further evidenced by the volume of pupils in SIMD 1 and 5 who attained the highest possible CfE level in reading in 2017, which was 38% and 79% respectively. (Scottish Government, 2018). In addition, the official publication regarding the destinations of pupils by highest attainment level, which is graphed below in figure 1.5, indicates the importance of early intervention when tackling academic attainment when seeking to avoid pupils moving to negative destinations such as unemployment after education.

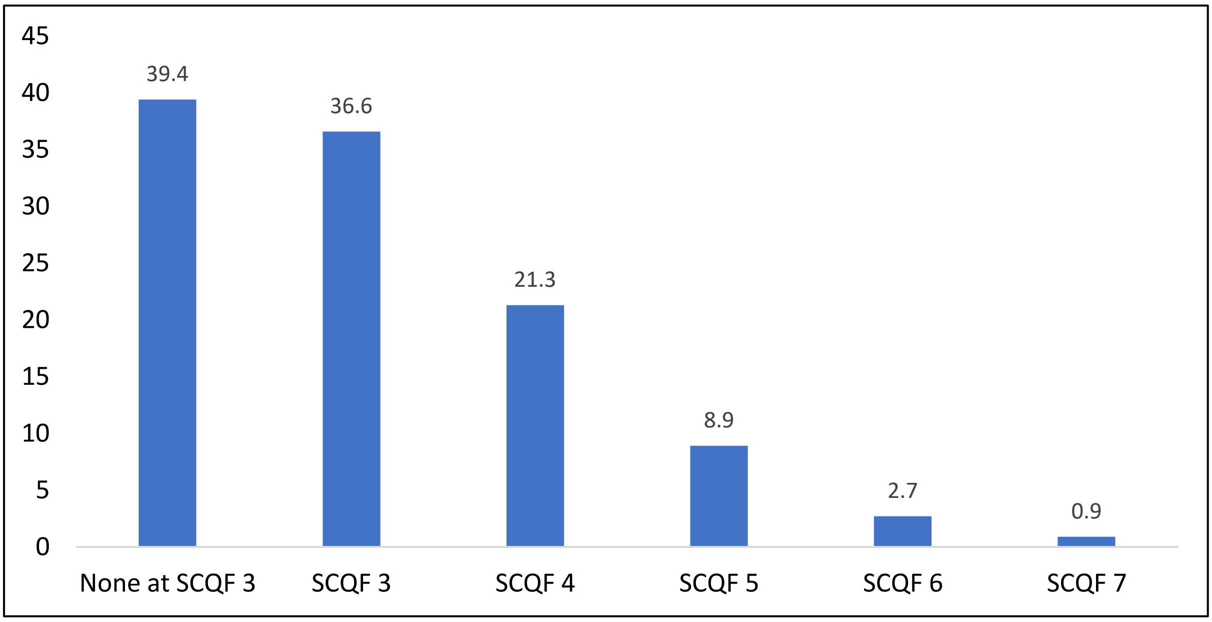

Figure 1.5 – Percentage of Scottish School Leavers Moving to negative destinations by highest qualification – 2016/2017.

Considering the challenges outlined above with regards to both academic attainment and physical activity and the implication of failure to intervene early and successfully, it is unsurprising that there have been several intervention strategies designed with the purpose of improving both in primary school age children. A summary of this literature follows below.

2. Literature Review

2.1 Physical Activity

Many of the interventions into physical activity of children and their corresponding research are carried out in school, because children spend up to 33% of their day to day lives in this environment (Mura et al., 2015). Several of these school-based interventions have been the subject of several systematic reviews in the last 5 years (Mura et al., 2015; Naylor et al., 2015; Watson et al., 2017). Of these reviews, the largest completed by Mura and colleagues (2015) comprised of 47 studies of participant sample sizes ranging between 67 (Ardoy et al., 2013) and 5458 (Bonsergent et al., 2013), and intervention periods spanning from 5 days (Butcher et al., 2007) to 4 years (Simon et al., 2008; Marcus et al., 2009). The results of these studies overall portrayed a positive effect, but the degree of this impact was varied and was often insignificant. One potential reason for this variation in findings is the use of body mass index (BMI) as the primary measure of impact in 35% of the studies. While some of these studies observed a significant (p=<0.001-0.05) reductions in BMI (Bonsergent et al., 2013; Llargues et al., 2012; Brandstetter et al., 2012; Angelopolous et al., 2009; Sacchetti et al., 2013), research has indicated that despite being considered the universal parameter used to define weight, BMI comes with limited reliability for studies of children and young people as a result of frequent measurement error and the fact that there is significant seasonal variation in the BMI of most children (Freedman and Sherry, 2009; Wickramasinghe et al., 2005; Wilkes et al., 2019). Furthermore, this limitation is suggested to be emphasised by shorter intervention studies given that physiological adaptations measured by BMI frequently take longer to manifest than the intervention period would allow (Mura et al., 2015), as is backed up by the fact that the above studies finding BMI improvements did so over intervention periods between 1 and 4 years.

In addition, it is a shared limitation many of these studies that they fail to measure the psychological impact of interventions. This omission of psychological considerations could limit the validity of the research given the associations presented in literature between the enjoyment and appreciation of the value of physical activity, and regular participation thereof (Gourlan et al., 2016). This is again supported by the results of the study carried out by Araujo-Soares et al. (2009) who found that after a physical activity intervention built around increasing intrinsic motivation to exercise and the self-efficacy of the participants, the intervention group were completing 64 minutes more physical activity per week than the control group at a nine-month follow-up ($p=<0.001$), which indicates that interventions for physical activity should ensure to factor in and monitor the psychological impacts of the intervention being carried out.

2.1.1 Digital Technology and Physical Activity

Another major area of interest within physical activity research is that of the potential impact of digital technology (Partridge and Redfern, 2018). Health and wellbeing have witnessed significant developments in recent times in the way it operationalises technology, with several benefits attributed to this increase (Bunn et al., 2018; Klurfeld et al., 2018). One benefit of using technology to implement PA interventions is the increase in accessibility of content (Partridge and Redfern 2018), given the substantial increase in technological device ownership globally (Sirriyeh, Lawton and Ward, 2010). A number of studies have been conducted into the impact of implementing physical activity interventions through the use of digital technologies, a selection of which can be found below in table 2.1. These studies are most relevant to the current research given that they were conducted with intervention periods between 1-week and 6-months and used several different digital delivery methods including apps, websites, and games.

Table 2.1 – Summary of literature regarding digital technology interventions for physical activity. RCT = Randomised Controlled Trial; PA = Physical Activity; MVPA = Moderate-Vigorous Physical Activity; IG = Intervention Group; CG = Control Group

Review of Physical Activity Interventions Implemented using Digital Technology				
Author (Year)	**Method of Delivery**	**Design and Sample**	**PA Outcome + Measure Implemented**	**Result**
Cook et al. (2014)	Website with tailored PA advice	1050 children RCT 1-month + 3-month follow up	MVPA min/day Self-Reported	Increase of 59.14 mins/day at 3 months follow up (p=0.01)
Frenn et al. (2005)	Website	103 school children RCT 1 month	MVPA minutes/day Self-Reported	IG – Increase of 22mins/day PA CG – Decrease of 46 mins/day PA (p=0.05)
Garde et al. (2015)	Mobile App – PA rewarded by in-game currency	54 Children 1-Week Intervention	Steps Per Day and Minutes Per Day of MVPA Accelerometer	No Significant Change
Gilson et al. (2016)	Mobile Application with notifications and status updates	Pre-post within subject's design 20-week intervention	Daily + Weekly Step Counts Pedometer	No Significant Changes

Guthrie et al. (2015)	Website with financial reward for IG	182 children 3 group RCT 6-week intervention	MVPA mins/day Accelerometer	Significant difference between CG's and IG (P=0.001)
Newton et al. (2009)	Weekly text messages	78 children 2 group RCT 12-week intervention	Daily Step Count MVPA min/day Accelerometer	No Significant Results
Wang et al. (2015)	Mobile App with Daily Text Messages	2 Group RCT of children 6-week intervention	MVPA days/wk. meeting guidelines Steps per day Self-reporting and accelerometer data.	Increase in steps per day (p=0.01), MVPA days/wk. (P=0.04) and Total PA (P=0.02)
Walsh et al. (2016)	Mobile App with Goal setting and feedback	2 group RCT of children 5 Week intervention	Steps/day Accelerometer	Increase in daily steps for IG vs CG (p=0.001)

It is a strength of a number of these studies that they have used pedometers and accelerometers to record steps, distance, and intensity of PA given that they are suggested to limit the extent to which human error can impact on the reliability of research of this nature (Loveday et al., 2015).

Another important observation from the above table is that the majority studies showing a significant improvement ($p<0.05$) in the PA of their participants implemented a multi-component intervention in which the primary method of delivery is supplemented by either face-to-face contact or some other form of regular communication. This is in agreement with the findings of reviews of comparable literature such as that by Bort-Roig and colleagues (2014) Gal et al., (2018) in which it is concluded that due to their ability to impact on behavioural change these supplementary communications can catalyse the effects of interventions using digital technology.

Considering all of the points above, it could be argued that to maximise the potential effectiveness of interventions to improve the physical activity rates of children the pupil's ability to appreciate the value of physical activity must be considered. In addition, those seeking to improve physical activity should consider incorporating digital technology, in order to increase accessibility and improve the degree to which interventions can be personalised to the target group or individual. Finally, when seeking to record and influence physical activity levels it is important to exercise caution if using self-reporting measures with younger children, and to attempt to capture activity taking place within school hours as well as outside.

However, it is a limitation of a number of the studies above that their cost of delivery was not considered in their evaluation. This oversight is significant given the implication within literature that digital technology driven interventions can come with substantial expense, and therefore to ensure applicability of any findings it is important the reader be able to assess the affordability of such intervention protocols (Bort-Roig et al., 2014). Moreover, while several of these interventions have had success with components such as purely digitally driven methodologies, gamification and extrinsic rewards, none have adopted an approach which utilises a combination of digital and in person deliver to provide all of these components together, which the current research seeks to do.

2.2 Academic Attainment

Given the implications of poor attainment discussed in the previous section and the evidence demonstrating the importance of early intervention to help prevent longer term impact, several interventions for academic attainment exist (Evans et al., 2017). Unsurprisingly given the importance placed on numeracy and literacy by all educational bodies these primarily focus on the development of these areas, and most are specifically for pupils considered to be struggling. Pertinent intervention studies are summarised in tables 2.2 and 2.3 below.

Table 2.2 - Review of Literacy Interventions for primary and early secondary education. TA = Teaching Assistants; ES = Effect Size; p = Statistical Probability; 1-1 = One-to-One Delivery. *P=<0.05

Literacy Interventions Review					
Name of Intervention	**Frequency of Sessions**	**Length of Intervention**	**Delivery Method**	**Reported Effect**	**Cost (per Pupil)**
Phonics Interventions					
Butterfly Phonics	2 x 1-hour sessions per week	10-12 weeks	Small group sessions led by trained practitioners and TA's.	ES = 0.43* (Merrel and Kasim, 2015)	£108.50
Fresh Start	3 x 1-hour sessions per week.	22 weeks	Small group or 1-1 sessions (based on pupil needs	ES = 0.24 (Gorard, Siddiqui and See, 2015a)	£116
Rapid Phonics	1.5 hours per week	12 weeks (6 weeks each in primary and secondary school)	Group sessions delivered by teachers	ES = (-0.05) (King and Kasim, 2015)	£205
Oral Language Interventions					
Talk for Literacy	2 sessions per week (varied length	23 weeks	Small group sessions delivered by TA's	d = 0.33 (Styles and Bradshaw, 2015)	£29

Rhythm for Reading	1x 10-minute session per week	10 weeks	Small group sessions delivered by teachers	ES = 0.03 (Styles, Clarkson and Fowler, 2014).	£56
Philosophy 4 Children	1 session per week (varied length)	52 weeks (One Academic Year)	Whole class sessions delivered by teacher	Reading ES = 0.12 Writing ES = 0.03 (Gorard, Siddiqui and See, 2015b)	£16
Reading Comprehension Interventions					
Switch on Reading	Daily Sessions (mixed length)	10 weeks (minimum 40 sessions)	1-1 sessions delivered by TA's and Librarians	ES = 0.24* (Gorard, Siddiqui and See, 2015c)	£627
Reach	3x35 minute sessions per week	20 weeks	1-1 sessions delivered by specially trained TA's	ES = 0.34* (Sibieta, 2016)	£275 (£486 per TA)
Catch Up Literacy	2x15 minute sessions per week	30 weeks (split between primary and secondary school)	1-1 sessions delivered by TA's	ES = 0.12 (Rutt, 2015)	£796
Paired Reading	1x20 minute session per week	16 weeks	1-1 sessions for all pupils delivered by	ES = (-0.02) (Lloyd et al., 2015)	£10.50

			year 9 pupils within the school		
TextNow	Daily 20-minute sessions (with additional reading to be done for 20 minutes a day out with intervention)	15 Weeks (split between primary and secondary education)	Small group sessions delivered by volunteer coaches	ES = (-0.06) (Maxwell et al., 2014)	£112
Accelerated Reader	Flexible	20 Weeks	Teachers agree goals with pupils for independent reading	ES = 0.24 (Siddiqui, Gorard and See, 2016)	£9
Blended Literacy Interventions					
Vocabulary Enrichment Full Intervention Programme	Replacement for mainstream English Lessons	19 weeks	Teacher delivered sessions to smaller than average classes	ES = 0.06 (Styles et al., 2014)	£75
Units of Sound	1x60 minute session and 1x30 minute session per week	18 weeks	1-1 sessions delivered by Specially trained teachers or TA’s.	ES = (-0.08) (Sheard, Chambers and Elliot, 2015)	£250

Perry Beeches Coaching Programme	5x1-hour sessions per fortnight	52 Weeks (One Academic Year)	1-1 Sessions delivered by external graduate coaches	ES = 0.36* (Lord et al., 2015)	£1,400

Table 2.3 - Review of Numeracy Interventions for primary and early secondary education. TA = Teaching Assistants; ES = Effect Size; p = Statistical Probability; 1-1 = One-to-One Delivery

UK Based Numeracy Interventions Review					
Name of Intervention	**Frequency of Sessions**	**Length of Intervention**	**Delivery Method**	**Reported Effect**	**Cost (per Pupil)**
Catch Up Numeracy	2x15 minute sessions per week	30 Weeks	1-1 sessions delivered by TA's	ES = 0.21 (Coleman, 2014)	£130
Philosophy 4 Children	1 session per week (varied length)	52 weeks (One Academic Year)	Whole class sessions delivered by teacher	ES = 0.10 (Gorard, Siddiqui and See, 2015b)	£16
Every Child Counts	Various depending on type of account used.	Various depending on type of account used	1-1 sessions delivered by university students or recent graduates	ES = 0.33* (Togersen et al., 2013)	Not Reported
Mathematics Recovery	4/5x30 minute sessions per week	12 weeks	1-1 sessions delivered by specially trained teachers	ES = 1.14* (Smith et al., 2013)	US$3000
Number Rockets	3x40 minute sessions per week	16 weeks	Small group sessions delivered by trained TA's	ES = 0.34* (Rolfhus et al., 2012)	US$100-150

1st Class@Number	3x30 minute sessions per week	10 weeks	1-1 or small group sessions delivered by TAs or teachers	ES = 0.18 (Nunes et al., 2018)	£77 (not including training of staff).
Maths Facts in a Flash	3x15 minute sessions per week	15 weeks	Computer Based Programme delivered by teachers	ES = 0.3 (Burns, Kanive & DeGrande (2012)	Not Reported
Tom's Rescue	2x60 minute sessions per week	5 weeks	Pupil led focussing on 18 educational computer games	ES = 1.45* (de Castro et al., 2014)	Not Reported
GraphoGame Math	5x15 minute sessions per week	3 weeks	Computer Games completed by the pupils	ES = 1.04* (Salminen et al., 2015)	Not Reported
The Number Race	4x30 minute sessions per week	4 weeks	Adaptive computed game completed by the pupils	ES = 0.8 (Wilson et al., 2008)	Not Reported

Within these interventions a wide range in effect can be seen in both the literacy and numeracy attainment of children, with effect sizes from d= -0.08 (Sheard, Chambers and Elliott, 2015) to d=1.45 (deCastro et al., 2014) published. It is a strength of all studies cited above that they have used the Cohen's d method of calculating effect size (Cohen, 1988) given its previously stated accuracy (Maxwell, Kelley and Rausch, 2008). However, considering that Cohen (1988) suggested that approximately 300 participants are required to confidently recognise a small effect, it is a limitation of some studies above that they have small sample sizes (deCastro et al., 2014; Salminen et al., 2015; Wilson et al., 2008). Furthermore, when looking at the studies collectively it can be observed that in interventions where pupils are taken out of class to complete the intervention in a one-to-one environment, the effect on their academic attainment is greater (Gorard, Siddiqui and See, 2015a; Gorard, Siddiqui and See, 2015c; Sibieta, 2016; Rutt, 2015; Lloyd et al., 2015; Sheard, Chambers and Elliot, 2015; Lord et al., 2015; Coleman, 2014; Togersen et al., 2013; Smith et al 2013; Nunes et al., 2018). This increased performance of one-to-one interventions is in agreement with earlier research by Cohen, Kulik and Kulik (1982) in which they conclude it allows for a more tailored approach to their individual learning needs. On the other hand, while a number of studies discovered significant effect (p=0.001-0.005) with one-to-one delivery this can be seen to significantly increase the cost of the programmes, with some such programmes costing up to US$3000 per pupil (Approximately £2,167.32; Mathematics Recovery; Smith et al., 2013).

Finally, when looking collectively at the studies of literacy and numeracy it is clear that many of the most impactful interventions approach the challenge of improving academic attainment holistically through the use of a multi-level intervention (Styles et al., 2016; Sheard, Chambers and Elliot, 2015; Lord et al., 2015; Gorard, Siddiqui and See, 2015b) in which digital technology was used as the primary method of delivery (Maxwell et al., 2014; Gorard, Siddiqui and See, 2015b; Lord et al., 2015; Burns, Kanavie and DeGrande, 2012; deCastro et al., 2014; Salminen et al., 2015; Wilson et al., 2008). This is in agreement with previous studies (Berninger, Fayol and Alston-Abel, 2011; Fuchs and Vaughn et al., 2012) who have highlighted the importance of accessibility and adaptability when aiming to improve the literacy and numeracy of children. Moreover, this finding that digital technology can improve the success of literacy and numeracy interventions is comparable to the conclusions of several reviews (Seo and Bryant, 2009; Slavin et al., 2011; Kucian et al., 2011; Schoppek and Tulis, 2010) in which it is proposed that digital technology allows sessions to be tailored to the individual needs of pupils to a greater extent than traditionally delivered interventions.

Considering the above, it can be concluded that where possible technology should be incorporated into future interventions for pupils AA, considering its proposed ability to allow repetitive practise, immediate and specific feedback, and a motivational environment for school-aged participants (Salminen et al., 2015). These attributes are all considered to be essential to develop literacy and numeracy (Baker, Gersten and Lee, 2002; Fuchs et al., 2008; Gersten et al., 2009).

2.3 Combined Interventions for Physical Activity and Academic Attainment

It has been acknowledged in several extensive reviews that physical activity and the cognitive performance of people of all ages are positively correlated

(Donnelly et al., 2016; Mandolesi et al., 2018; Gomes-Pinilla and Hillman, 2013; Ahlskog et al., 2011; Bherer, Erickson and Liu-Ambrose, 2013; Ohman at el., 2014; Etnier et al., 1997). Reviews by Sibley and Etnier (2003) and by Etnier et al., (1997) have reported effect sizes of d=0.32 and d=0.25 on the cognitive performance with increased physical activity levels from 125 samples over 44 studies and 1260 samples over 134 studies, respectively. There are several proposed explanations in literature for the correlation between physical activity and cognitive performance. One potential explanation is that physical activity affects cerebral capillary growth, and that this in-turn increases blood flow and oxygenation to the brain (Cotman, Berchtold and Christie, 2007; Delp et al., 2001). In addition to this, it has also been suggested (Cotman and Berchtold, 2002; Rybak, Somani and Ravi, 1995) that physical activity can increase the level of neurotransmitters and neurotrophins in the brain, leading to an improved ability to perform cognitive tasks. However, it is noted in the review of physical activity and its relationship to cognitive performance carried out by Donnelly et al., (2016), that this is an area of literature that is in much need for further and more comprehensive research, meaning caution must be taken when interpreting the above findings.

Despite the strength of correlational evidence between physical activity and cognitive performance, the volume and quality of evidence regarding the impact of physical activity on academic attainment is much weaker, with a number of reviews identifying mixed results (Donnelly et al., 2016; Singh and Staines, 2015; Burkhalter and Hillman, 2011; Penedo and Dahn, 2005; Keeley and Fox, 2009; Santana et al., 2017). As with the mixed findings discussed in other sections of this review however, a number of methodological explanations exist for this fluctuation. For example, cross sectional analyses have identified a positive correlation between academic attainment and physical fitness factors (r=0.26-0.56; p=0.001-0.05; Blom et al., 2011; Castelli et al., 2007; Chomitz et al., 2009; Coe et al., 2012; 2013; Van der Niet et al., 2014), however these studies did so without correcting in any way for variables such as family situation, age or nutrition. It has been suggested in related research that variables such as these can impact upon the relationship between physical fitness and academic achievement, and therefore caution must be taking when evaluating these results (Donnelly et al., 2016; Keeley and Fox, 2009).

Within intervention trials it is a challenge of much of the literature that a wide variety of assessments for both physical activity and academic attainment have been used, and that most studies give little or no indication as to the specific parameters of the physical activity used in the intervention such as frequency, intensity, and duration of activity (Donnelly et al., 2016; Burkhalter and Hillman, 2011; Penedo and Dahn, 2005). It has been hypothesised that these are the main issues in identifying a consistent trend in the impact of physical activity and academic attainment, because of the fact that physical activity elicits specific benefits to cognitive performance and academic attainment, and that by failing to examine the correct activity for the corresponding academic qualities studies may present false negatives (Donnelly et al., 2016).

2.4 Physical Literacy

2.4.1 Definition of Physical Literacy

Physical literacy has recently gained traction within academia (Delaney et al., 2008; Higgs et al., 2008; Mandigo et al., 2009), to the point that there is now over 10 times as much research dedicated to its understanding, progression and application than there was 20 years ago (Keegan et al., 2015; Edwards et al., 2017a). Being physically literate is suggested to have a number of associated benefits such as improved levels of physical activity (Spengler and Cohen, 2015; Giblin, Collins and Button, 2014), behaviour, psychological variables and social wellbeing (Edwards et al., 2017a; Bellew, Bauman and Brown, 2010). One challenge facing the field of physical literacy is a large degree of variation in definitions attributed to the concept (Edwards, 2017a; Keegan et al., 2013), accompanied by a noticeable lack of analysis and critique of what it means to be physically literate. (Robinson and Randall, 2017). A relevant example of this comes from the United States' society of Health and Physical Educators (SHAPE), in which the term "Physically Literate," replaced the term, "Physically Active," when revising their national physical education standards document, in a manner that would suggest the two are interchangeable (Robinson and Randall, 2017). Such confusion amongst terms and the lack of a consistently applied definition is regarded as a significant factor when faced with a disparity of meaningful research (Edwards et al., 2017a). Moreover, the failure of researchers within the field to work with a level of consistency and transparency surrounding the definition of physical literacy increases the risk that the term may become meaningless by association, as well as limiting the validity and reliability of much published research. (Edwards et al., 2017a; Lakatos, 1970).

One of the most prominent authors within the field of physical literacy is Margaret Whitehead (Roetert and Jefferies, 2014), whose definition (Whitehead, 2013) is for physical literacy is as follows:

"The motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for maintaining purposeful

physical pursuits and activities throughout the life course." (Whitehead, 2013; page 28).

There are several reasons this definition is one of the most cited in the field (Robinson and Randal, 2017), and resultingly will be the definition adopted within the current research. Firstly, the definition acknowledges the philosophical underpinnings of the concept of physical literacy. Within her earlier work, Whitehead (2001;2010) suggests that there are three major philosophical theories behind physical literacy: monism, existentialism and phenomenology, each of which are captured within this definition. If researchers are unable to relate the proposed mechanisms through which a concept influences and is itself influenced, it risks limiting/degenerating the extent to which a scientific theory is being tested at all (Lakatos, 1970). Accordingly, it is important that the definition selected within this research allows for a detailed examination of both the findings and their potential philosophical underpinnings which the 'Whiteheadian,' definition would appear to. In addition, this definition refers to the concept of physical literacy, "throughout the life course," (Whitehead, 2013; page 28). This acknowledgement of the longevity of the theory is considered a strength, following recommendation that in order to be considered physically literate one must appreciate the value of and participate in a healthy and physically active lifestyle throughout all phases of life (Edwards et al., 2017a). Finally, the Whitehead (2013) definition identifies all the major aspects of physical literacy and the fact that they should be viewed as components of indivisible whole, as portrayed by Robinson and Randall (2017) in figure 2.1 below.

Figure 2.1 - Physical Literacy Elements (Robinson and Randall, 2017)

As such any attempt to assess physical literacy, its development, and indeed its impact in any context should include reference to and evidence of assessment of each of these key components if it is to be considered to come with a high level of content validity. This is again further evidenced by the work of Whitehead (2010) in which she states that focussing on one or a sub-group of these factors does not constitute an examination of physical literacy, suggesting that attempts to examine the potential of the theory with regards to the academic attainment of children should take this approach.

2.4.2 Physical Literacy and Academic Attainment

The benefits of physical literacy have led to interest in the potential of the concept when seeking to optimise the development and education of children (Dudley, 2015; Tremblay, 2012). However, within current academic literature, there is a lack of research specifically addressing the impact of an individuals' degree of physical literacy on their academic attainment. A potential reason for this lack of research is the previously discussed variety of definitions for physical literacy (Edwards et al., 2017a) leading to challenges when attempting to measure the association it has with aspects of academic performance.

The theory that motor skill development is linked to cognitive function can be dated back as far as 1954 when Piaget proposed cognitive skills and their development to be based around sensorimotor experience (Piaget, 1954). Since this initial proposal, several researchers have examined the relationship between motor skills and academic attainment using both cross-sectional and longitudinal methodologies as reviewed by MacDonald et al., (2018) and summarised below in table 2.4 and figures 2.2 and 2.3.

*Table 2.4 - Studies observing a positive relationship between motor variables and academic performance. * - p= ≤0.05*

Motor Variable	Maths	Reading
Fine Motor Proficiency	Kim et al., 2018* Pitchford et al., 2016* Roebers et al., 2014* Van Niekerk, Du Toit and Pienaar, 2015*	Cameron et al., 2012* Roebers et al., 2014* Suggate, Pufke and Stoeger, 2018*
Fine Motor Integration	Becker et al., 2014* Dunn, Loxton and Naidoo, 2006* Duran et al., 2018* Kim et al., 2018* Lachance and Mazzocco, 2006* Pitchford et al., 2016* Verdine et al., 2014*	Becker et al., 2014* Bellocchi et al., 2017* Cameron et al., 2015* Dinehart and Manfra, 2013* Dunn, Loxton and Naidoo, 2006* Geersten et al., 2016* Lachance and Mazzocco, 2006* Manfra et al., 2017* Memis and Sivri, 2016* Papadimitriou and Vlachos, 2014* Pienaar, Barhorst and Twisk, 2014* Pitchford et al., 2016* Santi et al., 2015* Schatschneider et al., 2004* Sortor and Kulp, 2003* Suggate, Pufke and Stoeger, 2018*
Manual Dexterity	Cameron et al., 2012*	Cameron et al., 2012*

	Dinehart and Manfra, 2013* Haapala et al., 2014* Manfra et al., 2017* Morales et al., 2011* Roebers et al., 2014*	Dinehart and Manfra, 2013* Doyen et al., 2017* Haapala et al., 2014* Manfra et al., 2017* Roebers et al., 2014* Suggate, Pufke and Stoeger, 2018*
Total Fine Motor Score	Cameron et al., 2012* Pagani and Messier, 2012* Pagani et al., 2010* Son and Meisels, 2006* Suggate, Stoeger and Fischer, 2017*	Cameron et al., 2012* Pagani et al., 2010* Potter, Mashburn and Grissmer, 2013* Son and Meisels, 2006* Suggate, Pufke and Stoeger, 2018*
Upper Body Limb Coordination	Aadland et al., 2017a* Jaakola et al., 2015* Morales et al., 2011* Rigoli et al., 2012*	Aadland et al., 2017a* Chang and Gu, 2018* Jaakola et al., 2015* Rigoli et al., 2012*
Balance	Lonnemann et al., 2011*	
Bilateral Coordination	Murrihy, Bailey and Roodenburg, 2017*	Murrihy, Bailey and Roodenburg, 2017*
Total Gross Motor Score	Aadland et al., 2017b* Cameron et al., 2012* Haapala et al., 2014* Jaakola et al., 2015* Kurdek and Sinclair, 2001* Magistro, Bardaglio and Rabagletti, 2015*	Aadland et al., 2017b* Cameron et al., 2012* Chang and Gu, 2018* Jaakola et al., 2015* Kurdek and Sinclair, 2001* Pagani et al., 2010*

	Pagani and Messier, 2012* Son and Meisels, 2006* Xiang et al., 2017*	Sigmundsson et al., 2017* Son and Meisels, 2006*

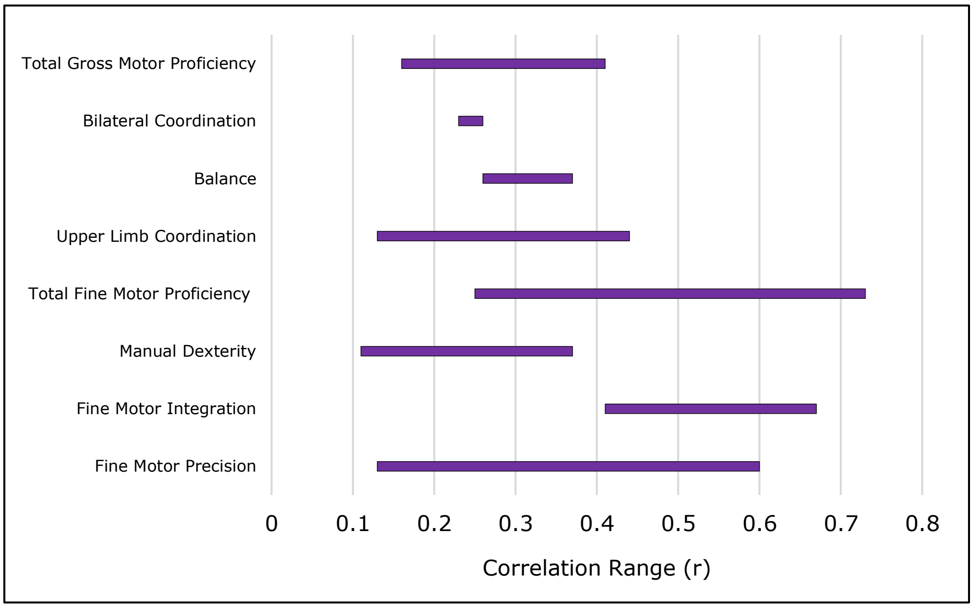

Figure 2.2 - Range in Correlations reported between motor variables and Maths Performance by studies in table 2.6. r = Correlation

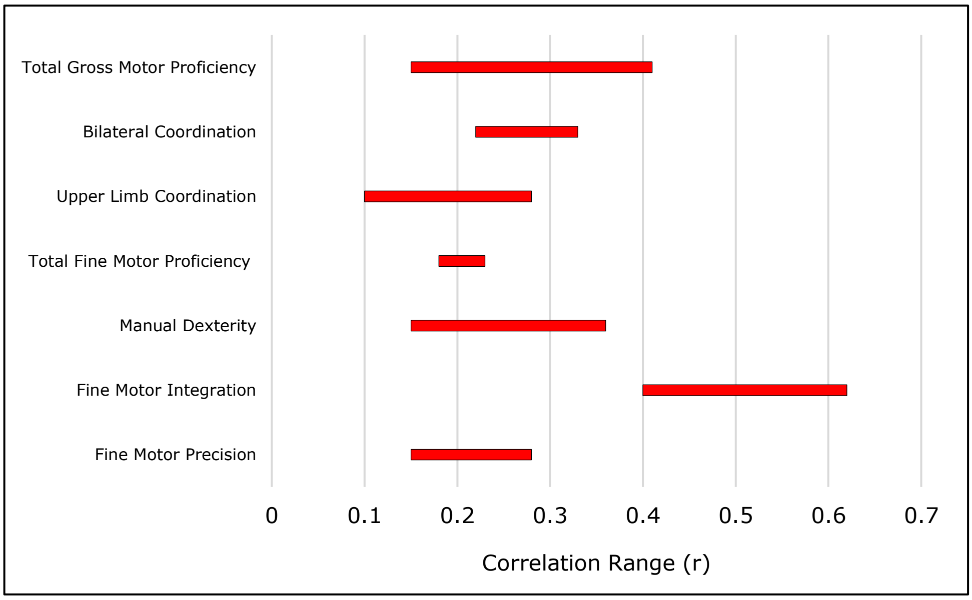

Figure 2.3 – Range in Correlations reported between motor variables and Reading Performance by studies in table 2.6. r = Correlation

In addition to these correlational investigations, several studies have examined the effect of motor proficiency related interventions on academic performance (Erasmus et al., 2016; Beck et al., 2016; Callcott, Hammond and Hill, 2015; Ericsson and Karlsson, 2014). These interventions range from 6 weeks (Beck et al., 2016) to 3 years (Ericsson and Karlsson, 2014) and all found significant effect ($p=0.012 – 0.05$) with results reported by Erasmus et al., (2016) demonstrating the largest effect ($d=1.13$).

It is a strength of these studies that the majority have carried out regression analyses as part of their methodology, to account for variations such as executive functioning and visual skills (MacDonald et al., 2018). The importance of such regression analysis is suggested by Beck and Colleagues (2016), who identified that when following a motor skill intervention for academic attainment, only 10.1% of the improvement post-intervention was attributable to developments in fine motor skill. As well as highlighting the link between motor skill and mathematic performance this allows researchers to appreciate the importance of measuring and accounting for factors such as such as IQ and Phonological Awareness in future research (Kurdek and Sinclair, 2001; Mayes et al., 2009; Schatschneider et al., 2004; Santi et al., 2005). One major conclusion that can be drawn when examining these studies collectively is that greater effects are achievable when participants are still in the early stages of education. This conclusion comes from the fact that in over 85% of the studies evaluated above in which significant relationships were observed ($p= <0.05$; MacDonald et al., 2018), the participants were aged between 4 and 11 years old. This agrees with findings in similar reviews (Fels et al., 2015) and would suggest that when working with pupil's academic attainment and motor skill development that early intervention should be priority of any future strategy. On the other hand, considering the belief (Luo et al., 2007) that a ceiling effect is produced on the relationship between motor skills and academics as pupils reach a level of autonomy regarding their movement capabilities, the limited significant of findings in studies of older children may not be an accurate reflection of those struggling learners within the year groups for whom targeted intervention strategies are most commonly recommended.

However, it was not the intention of the above research to examine or discuss the extent to which these relationships and their development impact on the holistic development of the children. This is important considering the impact potential of improving individual physical capabilities observed, as well as the relationship between physical activity, emotional wellbeing and psychological factors such as confidence and motivation with academic achievement discussed previously (Whitehead., 2013; Donnelly et al., 2016; Almond, 2013). Furthermore, one must consider the belief that the true value in these factors of physical literacy is in their consideration as indivisible and interrelated components of a holistic approach. This argument, therefore, demonstrates a need for future research to examine the operational potential of physical literacy as a concept when seeking to further both the academic attainment and physical activity of children and young people.

2.5 STEP Physical Literacy:

The STEP Programme was launched in 2016 and is available to primary and secondary schools across the UK (STEPTODAY, 2019). The objective of STEP is to use physical literacy-based exercises to improve upon the academic attainment and physical competencies of pupils participating in the intervention. Further information about the programme and its utilisation can be accessed at https://www.region10.org/programs/step-physical-literacy/overview/ where a case study of data from the United States of America is presented (STEP2Progress). The Programme was created for pupils aged 7 to 13 who do not suffer from any significant cognitive or physical impairment and involves the completion of two physical movement sessions each school day for two academic years. The STEP programme utilises digital technology for its delivery, with each pupil receiving a personalised profile accessed via mobile, tablet or laptop, where their exercises are marked by a teaching assistant (TA). Pupils can also interact with the technology by monitoring the levels they are reaching in certain disciplines, as well as tracking their attendance through animated dials. These sessions require pupils to be removed from the class environment for approximately 10 minutes each session and are assessed on a 4-point Likert scale for performance (STEPTODAY, 2019). Using a proprietary self-learning algorithm, the STEP Programme then uses these marks to prescribe the exercises the pupils will receive in up-coming session to ensure the sessions are relevant to developmental needs of the pupil (STEPTODAY, 2019). These sessions come from one of three distinct groupings: Balance, Eye Tracking or Coordination and start at a foundational level (level 1). When pupils are perceived to have developed the skills to complete these movements consistently and correctly, they progress onto the next level. Exercises completed in the morning are the same in the afternoon, and pupils can reach a maximum of level 16 in each discipline.

As discussed in section 2.4, there are a range of studies which have strongly suggested a link exists between elements of physical literacy such as balance, coordination and motor skill development and the attainment of children in school settings. The STEP programme prescribes exercises in a personalised way, with a view to identifying and developing areas of weakness within pupils from the physical competencies above, and so theoretically should serve to improve upon the academic attainment of these children in the manner highlighted above in previous peer-reviewed research.

Moreover, the STEP programme is further aligned to the concept of physical literacy in as much as it takes place daily, furthering the pupils understanding and appreciation of the value and importance of daily activity throughout the life course.

2.6 Summary:

It is clear both physical activity and the academic attainment of children and young people are areas of public interest requiring further and more specific research. In addition to this increased specificity, it should be a priority of research to further examine the impact of digital technology on the accessibility of both challenges. Consideration must also be given to the significant financial constraints in education and the implication above that failing to consider cost effectiveness limits study validity in this field (Levin and McEwan, 2001). Resultingly, it should also be a priority of future research to examine the effects of interventions relative to the costs accrued in their development and implementation.

Physical Literacy is a concept gaining much traction in recent literature which may serve to bridge the gap between physical activity and academic attainment interventions within schools (Edwards et al., 2017a). However, while much research has confidently demonstrated a relationship between several of the components of physical literacy and both physical activity and academic attainment, the research seeking to demonstrate the ability of an intervention using these competencies has been much more varied. Most significantly however, as of now there have been no studies of the required methodological strength to confidently demonstrate the impact that physical literacy as a holistic concept could have on the academic attainment of children in an educational setting. Initially, as a UK wide programme with an excess of one thousand pupils participating the intention was to use the STEP Programme to deliver a comprehensive analysis of the effects of physical literacy derived intervention delivered in a digital platform on the academic attainment and physical activity of school pupils. However, due to substantial logistical challenges, and the dissolution of the programme in large parts of the country, a much smaller and regionalised approach was required.

Resultingly, the aims of the current study were as follows:

1. To investigate the influence of a physical literacy intervention delivered using digital technology in Scottish primary school settings on the physical activity and academic attainment of children

2. To evaluate the cost effectiveness of this intervention.

To effectively meet these aims, the study had the following objectives:

1. Implement a battery of assessments that would allow for the assessment of physical literacy.
2. Assist with collection and analysis of academic attainment data which was taking place within the case study cohort.
3. Collect cost data for all components of the case study intervention through interviews with senior management staff in participating schools.
4. Perform cost-effectiveness analysis and compare to commonly implemented interventions.

3.0 **Methodology**

All participant data was shared with the university by STEP for research purposes as part of a separate piece of academic work and ethics were sought and received to use in the above research study. Initially, participant data was shared with STEP2Progress for the purpose of tracking and monitoring purposes. This was carried out by the researcher in his role as an employee of STEP2Progress prior to the commencement of the research project. Once the research project had received approval and ethics were agreed, this data was then shared with the university with consent from both STEP2Progress and the head teacher of each participating schools in an anonymised format for the purpose of use in an academic research project. This was again done by the lead researcher, this time in their capacity as the project owner of the current academic research project.

3.1 Study Design

To assess the effectiveness of the intervention protocol on academic attainment of the pupils, a case study approach was implemented with evaluation taking the form of control trial with elements of repeated measures. It has been frequently acknowledged in literature (Kendall, 2003; Ernest, Jandrain and Scheen, 2015) that it is the gold standard when seeking to establish intervention effect. On the other hand, there are several implementational challenges which have been reported when attempting to apply such a methodology within educational settings (Kendall, 2003). These include principally an increased cost and time commitment for the researchers, as well as the logistical and ethical challenges which come with adapting the day-to-day learning of a number of pupils within a school (Cartwright and Munro, 2010). These challenges are particularly reflective of this research considering the intervention commenced 6 months prior to the academic study, thus limiting the authors ability to impact upon its design. Resultingly, it was not considered possible within this intervention to randomise allocation to the intervention (IG) and control group (CG) when assessing the intervention impact on the holistic development of the pupils. Instead, a case study design was implemented in which the intervention group's baseline values acted as the control from which their improvements are measured. This approach has been suggested by Lipsey et al., (2012) to be an effective method of demonstrating the effectiveness of an intervention in primary school education, particularly when considering the variances in needs and their manifestations in pupils at this stage of their development.

3.2 The STEP Programme

The Programme was created for pupils aged 7 to 13 who do not suffer from any significant cognitive or physical impairment and involves the completion of two physical movement sessions each school day for two academic years. These sessions require pupils to be removed from the class environment for approximately 10 minutes each session and are delivered by teaching assistants (TA's) who have received a half day of training specific to the intervention prior to delivery (STEPTODAY, 2019). These sessions come from one of three distinct groupings: Balance, Eye Tracking or Coordination and start at a foundational level (level 1). Pupils join the TA delivering their session, remove their shoes and are briefed on the activities of the day. During this briefing they are given a summary of the key coaching points for each exercise via the digital platform, as well as watching a short clip of a model performance that they will then attempt to emulate. Once complete, the session is debriefed with the TA asking what the pupil felt of it and their performance, before delivering a grade from the 4-point likert scale. The pupil is then returned to class and will repeat the same process later in the day. When pupils are perceived to have developed the skills to complete these movements consistently and correctly, they progress onto the next level with a maximum attainable level for each discipline of 16. In his role as a STEP Education Officer, the lead researcher was initially responsible for the training of all TA staff who would be delivering sessions. Following this, the lead researcher was then responsible in his capacity as a STEP employee for the collection, monitoring and analysis of attendance and performance data for all pupils on the intervention programme. This data was then part of the overall package of information anonymised and shared with the academic institution for research purposes, where the lead author was responsible for its analysis and interpretation in line with the aims and objectives of the current research.

There are several features of the STEP delivery style that can be considered good practise based on previous research. For example, it is a strength of the STEP delivery protocol that TAs are delivering sessions, considering the suggestion (Farrell et al., 2010) that these staff can illicit positive results when working with pupils, and that the changes of this are increased when the staff are provided with specific training on the intervention. Another strength comes from the one-to-one delivery of the programme, which has been highlighted as an effective delivery methodology in review for both maths (Holmes and Dowker, 2014) and reading (Hall and Burns, 2018) in children performing below expected attainment, with the enhanced ability it provides staff to create a nurturing and impactful environment cited as a main cause for this (Cheney et al., 2013). Moreover, given the recommendations that to be optimally effective one-to-one interventions should involve a minimum of 3-5 sessions a week and that these sessions should be 30 minutes or less in duration, it can be argued that the STEP delivery model is strong and well justified in academic literature. It has also been observed Webb and Williams (2017) that there are a number of factors impacting upon the rate of development of a primary school aged pupil, and by Whear et al., (2013) that a major contributing factor to interventions in primary school children is the degree to which it is tailored to the individual. Resultingly, it is a significant strength of the STEP programme that pupils' exercises are determined by their own previous performances within the intervention, allowing them to progress at their own rate and focus on the challenges specific to them.

Finally, and as discussed in sections 2.2 and 2.3, it is a strength of interventions such as these in school environments that they use digital technology as a means of delivery, considering the impact it has been proposed to have on the accessibility and customisability they can facilitate (Scottish Government, 2015). Moreover, considering the well acknowledged specific nature of impact derived from both academic attainment and physical activity interventions in children when using digital technology (Mononen and Aunio, 2014; Donnelly et al., 2016) this strength is further emphasised.

3.3 Testing Protocol

Academic attainment scores were given by the classroom teachers of all IG pupils at baseline and following the completion of 12 months of the intervention. Within the control cohort of pupils these measures were recorded at the start of the intervention, and historically for a period 12-months before the intervention cohort began their intervention. Pupil questionnaires were also completed by the classroom teachers of all IG before and 12-months into the intervention. While it was not possible in this research project to measure pupils upon completion of the programme, by capturing this data at the 12-month midpoint consistency of intervention stage could still be attained for the evaluation across institutions. Exercise history, including the type, level, and perceived execution of exercise for each session was downloaded from the STEP platform for each IG pupil after 12 months of the intervention had been completed. Within their capacity as a STEP Education officer, the lead author was responsible for the collection and appropriate storing of this data for the company as a method of tracking and monitoring intervention effectiveness. When this data was agreed for sharing with the academic institution in an anonymised format under the consent protocol discussed in section 3.0, the lead author was then responsible for collection and processing of this data in the new anonymised format for the purposes of answering the research questions in section 2.6.

3.4 Participants

Participants for this research were selected using convenience-based sampling of pupils currently enrolled in the STEP Programme. These children were nominated for the Programme by their class teachers or deputy headteacher as a result of attaining below the expected level and/or because of concerns of regarding behaviour and an inability to work independently, as is the protocol in some comparable studies of intervention effect in educational settings (Holmes and Dowker, 2014; Clarke et al., 2014).

The control group used to establish the impact of the STEP intervention on academic attainment comprised of pupil’s convenience sampled from schools in the same city as the intervention. Data was collected one year prior to the date of intervention start, and again upon commencement of the intervention. Capturing information at these time points allowed researchers to compare changes observed in the intervention group to those that attained by pupils throughout a standardly delivered academic year. Pupils were selected for the control group following the same criteria as used to nominate pupils for the intervention group, given the suggested impact that classroom behaviour, degree of additional support needed and baseline academic ability have on a child's rate of academic improvement (Merrel and Kasim, 2015; Gorard, Siddiqui and See, 2015a; Rutt, 2015; Smith et al., 2013; O'connor, Swanson and Geraghty, 2010). The demographics of each group can be seen below in table 3.1.

Table 3.1 - Intervention and Control Group Pupil Demographics. SD = Standard Deviation

	Intervention Group	Control Group
Number of Participants	13	64
Age of Participants at Baseline in Years (SD)	8.4 (0.6)	8.3 (1.0)
Academic Attainment at Baseline (Scottish CfE Level)	2.3	1.9

Inclusion and exclusion criteria for the intervention group within this study is summarised below in table 3.2. An inclusion criterion of 70% commitment to STEP sessions was set for both individual pupils and for the schools they represent as a collective. This follows comparable studies setting similar criteria to ensure that the findings present an accurate reflection of the intervention's efficacy (Hawley-Hague et al., 2016).

Table 3.2 – Inclusion/Exclusion Criteria. RGU=Robert Gordon University

Inclusion	Exclusion
Aged between 7 and 13 throughout the full Programme	Any pupil aged out-with 7-13 at any point throughout the Programme
Meeting the minimum physical and cognitive competencies required to participate in STEP	Failure to meet the minimum physical and cognitive competencies required to participate in STEP.
School commitment must stay above an average of 70% per week throughout the case study	Schools' failure to maintain an average commitment of 70% of sessions per week throughout the case study period
Individual pupils must have a minimum of 70% commitment throughout the study	Failure to comply with the minimum commitment of 70% sessions.
Must start the Programme between March 2018 and March 2019, completing the intervention between March 2020 and March 2021	Failure to start/finish the Programme within these dates.
School willing to allow STEP to share academic and Pupil Questionnaire Data with Researcher.	School unwilling to allow STEP to share Data with RGU throughout the Programme

3.5 Study Measures

3.5.1 Academic Attainment Data

Academic data collection involved an assessment of each pupil's attainment in line with the standards expected at their chronological age within each area of the Scottish Curriculum for Excellence (Scottish Government, 2008), namely:

1. Reading
2. Writing
3. Listening and Talking
4. Overall Literacy
5. Mental Maths

6. General Maths
7. Health and Wellbeing (Scottish Government, 2008)

This was attained using a 5-point Likert scale in which teachers allocated pupils to one of the following categories based on their opinion and ongoing internal assessment of the pupil's performance:

1- Well Below Target
2- Below Target
3- On Target
4- Above Target
5- Well Above Target

As a result of the timings of the academic school year, teachers were not able to assess the pupils CfE levels at both baseline and the one-year point. Resultingly, the teacher who had the most experience with the pupils at the point of asking (for example, the teachers from the previous school year at the baseline data point collected as pupils began the new year) was asked to complete the evaluation. This ensured that pupils were assessed on their level by the teacher with the most detailed and specific knowledge of their status and progress relative to the guidelines within the CfE structure at all times, in order to maximise the reliability of findings. While some studies suggest that pre-post comparison of standardised assessment measures leads to the most valid and reliable evaluation of educational intervention, a number of studies have suggested teacher opinion measures such as these are a reliable measure with excellent concurrent validity compared to standardised tests (Kenny and Chekaluk, 1993, Gresham and MacMillan, 1997; Bennett, 2011), particularly in cases where participants are in the bottom academic quartile such as is the case in this research (Mercugliano, Power and Blum, 1999).

3.5.2 Pupil Questionnaire Data

The pupil questionnaire (Appendix 1) is the second core measuring tool implemented within schools across the UK when carrying out the STEP Programme. This involves 59 statements across 9 categories to be completed by the class teacher for each pupil, the details of which are in table 3.3 below. For each statement, the teacher categorises the pupil on a 4-point Likert scale as follows:

1- Not Really/Virtually Never (Scored as 0)
2- At Times (Scored as 1)
3- Frequently (Scored as 2)
4- Yes/Usually (Scored as 3)

Table 3.3 – Pupil Questionnaire Categories

Category	Number of Statements	Maximum Score Available
Self Esteem, Confidence and Emotional Wellbeing	6	18
Learning Behaviour, Social Behaviour and Social Skills	12	36
Executive Function + Sequencing	9	27
Balance and Coordination	6	18
Gross and Fine Motor Skills	5	15
Reading	6	18
Writing	4	12
Spelling	2	6
Maths	6	18

These questions were all written in the positive and are ordered in a randomised pattern to ensure that teachers consider statements fully and to deter from identifiable patterns influencing the scoring (Steyn, 2017).

As can be seen above, this questionnaire encompassed several aspects of physical literacy as proposed by Whitehead (2013) including self-esteem, confidence, and physical competencies. In addition, it seeks to supplement the academic information attained in the above section through specific questions focussed on some of the key areas of academic attainment at the primary school level (Curriculum for Excellence, 2008).

3.5.3 STEP Programme Data

STEP Programme Data was collected centrally within the STEP Database initially by the lead researcher in their capacity as a STEP employee for internal tracking and monitoring of the intervention. Once ethics and consent were confirmed for the current research, this data was shared with the lead author and academic institution for research purposes with pupils' details anonymised, and with the consent of both the academic institutes and STEP2Progress Ltd. The data captured for each pupil from the STEP programme is summarised below in table 3.4.

Table 3.4 – STEP Programme Data Collected

Percentage Attendance of the Intervention
Number of Very Easy Sessions
Highest Level Reached in Balance Exercises
Highest Level Reached in Eye Tracking
Highest Level Reached in Coordination
Sessions Attended
Sessions Missed

3.6 Data Analysis

3.6.1 Outcome Effectiveness

The Statistical Package for Social Sciences (SPSS, v.25) was used for all intervention effectiveness analysis. Logistic regression analysis was used to establish the odds ratio of an improvement in the attainment of pupils in line with each area of the CfE Curriculum for Excellence, 2008). Intervention group pupil's odds ratio of improving in each academic area were compared to those in the CG to establish the degree to which the intervention is likely to produce a positive effect. Given the variance in the intervals between academic attainment scores and the value of looking at each pupil individually, this method of analysis is preferable due to its ability to treat each variable independently and its previous successful use when demonstrating the effects of educational interventions (Huizing et al., 2006) and particularly when used regarding the academic attainment outcomes in primary school educational settings (McIntosh, Sadler and Brown, 2011).

Pupil questionnaire data was analysed using a paired T-test, to establish if there were a significant difference in pupils' pre to post-intervention scores (Roni, Merga and Morris, 2019). This method of statistical analysis is preferred given its ability to identify and interpret individual differences in the effectiveness of the intervention from pupil to pupil (Richards, Taylor and Ramasamy, 2013). In addition to this, effect sizes were calculated using the Hedges g (Hedges, 1981) calculation below (equation 3.1) to assess the statistical magnitude of the difference between the participants pre- and post-intervention scores in each aspect of the pupil questionnaire.

$$Hedges'g = \frac{1-3}{(4(n-1)-1)} * \frac{m1-m2}{SD\ pooled}$$

Equation 3.1 - Hedges' g Equation (Hedges, 1981).

Hedges G was the preferred method calculation for effect size in this research following suggestion by Rosnow and Rosenthal (2003) that it is a more valid measure than Cohen's D in instances of small samples sizes and when it cannot be assumed that the two samples will have a similar standard deviation.

To further contribute to the understanding of the impacts of the intervention correlational data was calculated for a number of factors. This follows the long-standing acknowledgement that correlational analysis allows the researcher to effectively assess the relationship between two factors, and in doing so to assess various components of an intervention relative to their impact on desired outcomes (Melnyk and Morrison-Breedy, 2012). The relationship between IG pupil attendance and overall improvement in academic attainment was calculated, as was the relationship between number of sessions completed which were considered, "Very Easy," by the TA and overall improvement in Academic Attainment. Engagement with, and adherence to, an intervention protocol has been consistently shown to integral to its ability to produce significant results across a number of fields including the improvement of academic attainment in children of comparable age to the current research (Leslie and Allen, 1999).

In addition, the relationship between the highest level of balance exercise reached and change in balance and coordination ability were examined. Alongside this, relationships between the highest level of coordination reached and perceived change in fine and gross motor skills were also be explored. It is acknowledged in both physical activity (Simms, Scarborough and Foster, 2015) and academic attainment (Johnston, 2011) interventions for children that the more specific the content is to the desired outcome, the greater effectiveness it is likely to have.

Finally, the relationship between maximum eye tracking level reached and improvement in literacy were examined for the IG. Eye tracking is considered one of the fundamental skills required to read and write proficiently (Shaked, Shamir and Vakeel, 2020; Anson, Schwegler and Horn, 2009) and it has previously been suggested that its improvement can significantly impact on the ability of an intervention to impact upon the literacy of school aged children (Anson, Schwegler and Horn, 2009).

Correlations were calculated using Spearman's calculation (Spearman, 1904) as below in equation 3.2. Again, this was preferred to a parametric alternative such as Pearson's given the need for such measures when ordinal values are analysed (Gravetter and Walnau, 2000).

$$r_s = 1 - \frac{6\sum D^2}{n(n^2-1)}$$

Equation 3.2 - Spearman's Correlation (Spearman, 1904).

3.6.2 Cost Effectiveness

3.6.2.1 Collecting Cost Data

Cost effectiveness analysis (CEA) was used in this research to better quantify the value of any improvements provided and is preferred to cost benefit analysis considering that these potential improvements will be measured in units of academic improvement rather than financial gains (Dhaliwal et al., 2012). In order to assess the cost effectiveness of the STEP Programme, it was necessary to ascertain the cost of delivering the Programme in as much detail as possible. To achieve this, the ingredients method was employed, in which all factors of delivering the intervention are noted and the costs incurred as a result of them identified (Levin and McEwan, 2001). This is a methodology commonly and successfully used within educational CEA (Levin and McEwan, 2001). As a former full time Education Officer with STEP, the researcher developed a list of ingredients in the first instance, drawing on their experience of the programme and its delivery within both intervention schools. In order to minimise the risk of researcher bias this list was then presented to headteachers of the participating schools during a telephone interview, so that they had the opportunity to make changes and edits from their professional perspective. This followed recommendation by several authors (Torgensen et al., 2006; Hollands et al., 2016; Levin and McEwan, 2001) that someone with extensive knowledge of the programme should be interviewed to compile a list of ingredients initially. AIngredients were categorised according to the work of Levin and McEwan (2001) into the following categories:

1. Personnel
2. Facilities

3. Equipment and Materials
4. Other Inputs

Costs incurred to STEP for the development and administration of the programme, and costs to the schools which would have been incurred regardless of the intervention's presence such as utilities and maintenance will not be included in this analysis, given recommendation that this can lead to an in-accurate view of the costs per unit improvement from the perspective of the school delivering and purchasing the intervention (Levin and McEwan, 2001).

3.6.2.2 Associating Costs with Ingredients

The total list of ingredients and their associated costs can be seen below in table 3.5. Costs were attributed to each of the ingredients identified to allow for an accurate comparison to other interventions with similar objectives. The CBCSE Cost Tool Kit (Hollands et al., 2015) was used to support the attribution of cost, listing each item of cost and the amount of it required to successfully replicate the Programme. This toolkit is specifically designed for the purpose of demonstrating costs associated with educational interventions and has been suggested to be valid and reliable by Hollands and colleagues (2016). Since both schools delivered the intervention using the same template for effective delivery that STEP propose, costs were calculated as a total across the two sites and divided by the total number of participants to give a cost per pupil ratio for the full one-year duration of the intervention (Hollands et al., 2016). Costs were then taken from a variety of sources such as the Scottish Government document for salary bandings (Scottish Government, 2019). Classroom assistants, teacher and deputy headteacher salaries were calculated and converted to an hourly rate inclusive of expected benefits (Hollands et al., 2016), and these rates were used to assign costs to the preparation for, and delivery of the programme, participation in training and time allocated for the tracking and monitoring of attainment and development. While it is acknowledged in research (Foster, Dodge and Jones, 2003) that costs associated participation in the research should not be factored in as they are not reflective of the intervention, STEP ask teachers to record this information as part of their tracking and monitoring protocol, and so it was included.

Equipment and Materials Costs included the licenses for the intervention, iPads for the delivery of sessions, and STEP equipment bags. Despite the fact that the total cost of licenses was donated by a third-party organisation these were included, given that the purpose of the evaluation is to calculate the cost of replicating the intervention and likelihood that this cost will usually be borne by the local authority itself (Hollands et al., 2016; Torgesen et al., 2006).

In keeping with the methodology of a comparable study (Hollands et al., 2016), Facilities were calculated using the cost of building an educational space within Scotland, which was identified per m^2 (Turner and Townsend, 2018). This was then increased by 30% to account for the cost of land, development, furnishing and equipment (Dunn and Laing, 2011). Both schools used small classrooms of approximately $20m^2$, this value was then used to calculate the market value of the classroom spaces over an annual period, before a percentage of the year the space was used for delivering training and the intervention itself was factored in to provide a cost for the space throughout the intervention (Hollands et al., 2016).

All costs were then portrayed in 2019 Pounds Sterling to ensure consistency when comparing them to other interventions and were divided by the effect sizes attained for both literacy and numeracy in order to produce a cost effectiveness ratio (Hollands et al., 2016).

Incremental cost effectiveness ratios (ICER) were then calculated by dividing the total cost of the intervention per pupil by the effect sizes attained where these were significant, as was done by Barrett and Van Der Heyden (2020) and proposed to be an accurate method of establishing cost effectiveness in educational settings by Levin and Garcia (2018).

Table 3.5 - Intervention Cost Effectiveness Ingredients Breakdown for One Year in one school

Ingredients	Cost (£)	Cost/Pupil (£)	Percentage of Total Cost (%)
Personnel Total	**3425.76**	**527.04**	**35.1**
Deputy Headteacher Time to Prepare School for STEP Intervention	311.44	47.92	
Class Teachers Completing Assessment of Pupils Pre- and Post-Intervention	289.92	44.55	
Class Teachers Time to attend STEP Training	247.74	38.12	
Teaching Assistants Time to attend STEP Training	44.39	6.83	
Teaching Assistants Time to Deliver STEP Intervention	1686.73	259.5	
Teaching Assistants Time to collect pupils from lessons and take them back after intervention	845.54	130.08	
Equipment and Materials Total	**3706.21**	**570.19**	**38.0**
STEP Programme License	3000.06	461.55	
iPads for Programme Delivery	631.16	97.1	
STEP Equipment Bags	74.80	11.54	
Facilities Total	**1985.43**	**305.45**	**20.3**
Classroom Space for Session Delivery	1908.16	293.56	
Classroom Space for STEP Training Session Delivery	26.38	4.06	
Classroom Space for Teachers Completing Assessment of Pupils Pre- and Post-Intervention	50.90	7.83	
Other Total	**964.88**	**115.38**	**6.6**
Intervention Total	9764.26	1,502.19	**100**

4.0 Results

4.1 Participation Data

Intervention attendance data is presented below in table 4.1. One pupil's attendance data was not made available by the participating institution. The remaining twelve pupils participated in a total of 11,511 intervention sessions (mean=959.3; SD=93.8), with an average overall attendance of 92.88%. An average of 82 of these exercises were considered to be very easy for the pupils by the TA delivering the session.

Table 4.1 - Pupil Intervention participation summary. SD=Standard Deviation

Pupil	Sessions Attended	Sessions Missed	Very Easy Sessions	Attendance (%)
1	1036	28	56	97.4
2	1054	10	41	99.1
3	964	98	44	99.8
4	1017	52	104	95.1
5	982	74	82	93.00
6	1053	16	25	98.5
7	1038	8	38	99.2
8	887	133	130	86.7
9	727	301	169	70.7
10	859	109	228	88.7
11	913	71	25	92.8
12	981	67	38	93.6
13	No Data Available			
Average	959.3	80.6	81.7	92.9
SD	93.8	76.8	61.8	7.8

4.2 Academic Attainment

The binary logistic regression results are summarised below in table 4.2. The number of pupils in the intervention group who recorded improvements in at least one of the measured outcomes was 84.6%, compared to 28.1% of the control group pupils. Being in the STEP intervention group versus the control group made it more likely that a pupil would move up a teacher assessed banding for Health and Wellbeing (OR=69.7; p<0.001). In addition, the model was able to identify that listening and talking (OR=11.3, p=<0.001) as well as writing (OR=6.7, p=0.017 were also significantly more likely to be improved by those within the intervention group than the control group. All other changes in odds of improvement in line with the CfE bandings were not statistically significant.

Table 4.2 - Binary Logistic Regression Results. OR = Odds Ratio; *p=<0.05; **p=0.01; ***p=<0.0001.

Curriculum for Excellence Variable	**OR**
Reading	5.6
Writing	6.7*
Listening and Talking	11.3**
Overall Literacy	2.7
Mental Maths	0.98
General Maths	0.01
Health and Wellbeing	67.7***

4.3 Pupil Questionnaire

The descriptive data to conduct paired T-tests are portrayed in figures 4.1 and 4.2 summarised alongside the Hedges g analysis in table 4.3. There were significant changes in the scores for Executive Functioning and Sequencing from pre- to post-intervention (t=5.69; p≤0.001) indicating that the STEP intervention had a positive impact on the development of the pupils in this regard. Similar positive changes were observed in the pre-post intervention scores for Balance and Coordination (t=3.4; p=0.005), Gross and Fine Motor coordination (t=2.4; p=0.035), Reading (t=3.0; p=0.01) Writing (t=5.196; p<0.001), Mathematics (t=2.395; p=0.034) and Impact on the Learning of Self and others (t=2.502; p=0.028). Small changes were also observed in Self Esteem, Confidence and Emotional Wellbeing, Learning and Social Behavioural Skills, and Spelling but these were not statistically significant. All of the changes above however, can be considered clinically relevant given that they suggest the STEP intervention lead to an improvement of components of development considered essential for optimal pedagogical development.

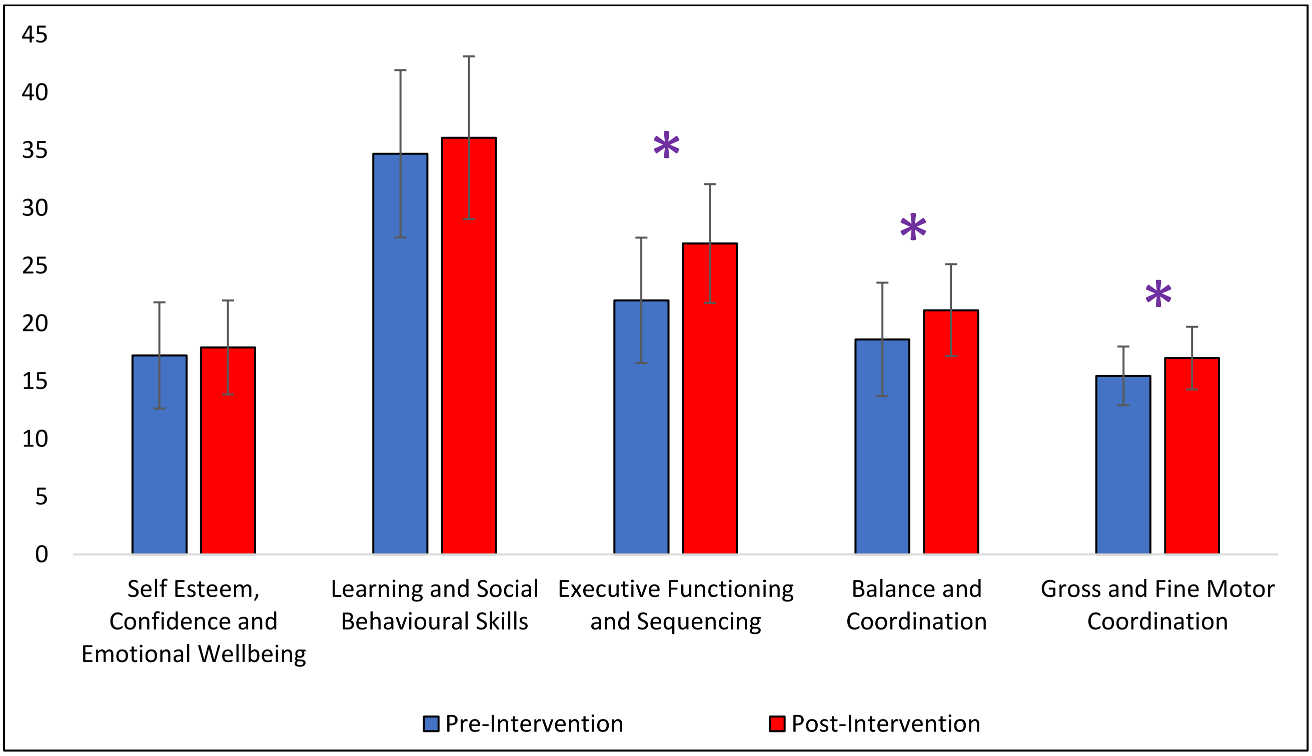

Figure 4.1 - Pre- and post-intervention pupil questionnaire results (a). *p=<0.05

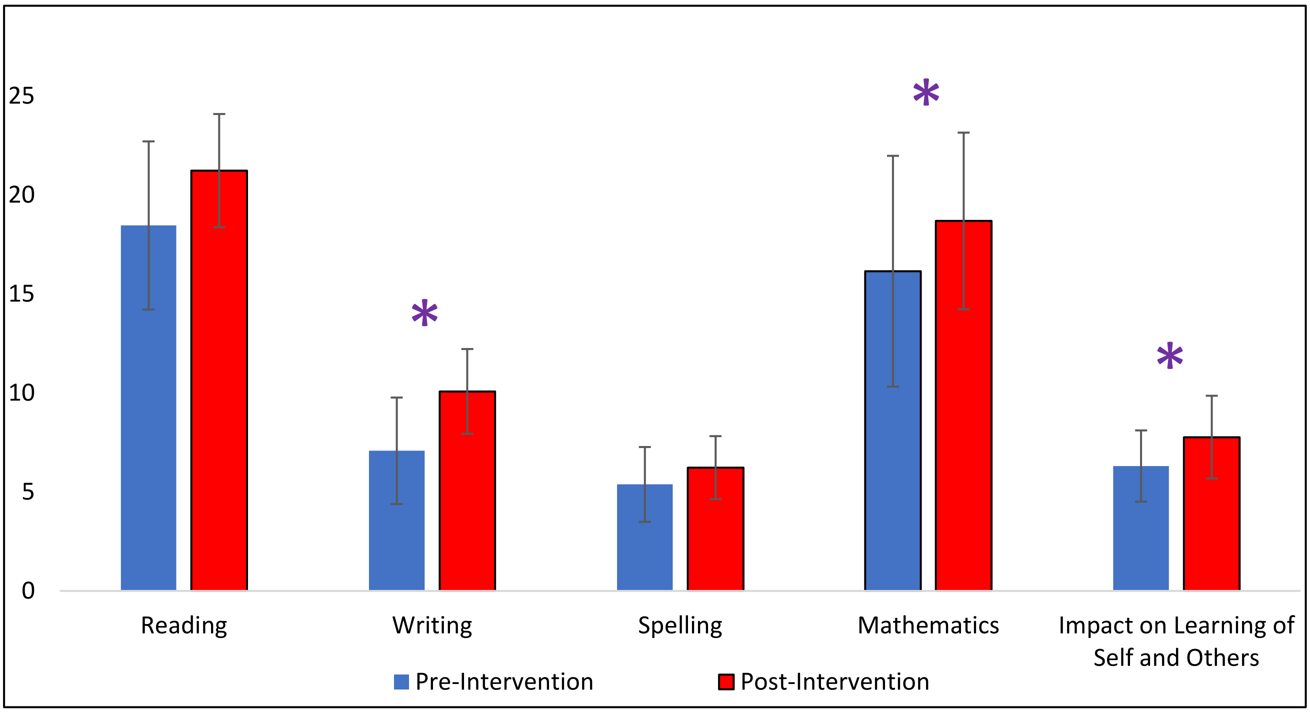

Figure 4.2 - Pre- and post-intervention pupil questionnaire results. (b) *p=<0.05

Table 4.3 - Pupil Questionnaire T-test results summary

Category	Pre-Intervention		Post-Intervention		Statistical Analysis			
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**t**	**df**	**p**	**Hedges' g**
Self Esteem, Confidence and Emotional Wellbeing	17.23	4.60	17.92	4.07	0.67	12	0.516	0.17
Learning and Social Behavioural Skills	34.69	7.24	36.08	7.05	1.315	12	0.213	0.2
Executive Functioning and Sequencing	22.00	5.43	26.92	5.14	5.687	12	0.0001*	0.97
Balance and Coordination	18.62	4.91	21.15	3.98	3.434	12	0.005*	0.59
Gross and Fine Motor Coordination	15.46	2.54	17.00	2.71	2.379	12	0.035*	0.61
Reading	18.46	4.25	21.23	2.86	3.03	12	0.010*	0.79
Writing	7.08	2.69	10.08	2.14	5.196	12	0.0002*	1.28
Spelling	5.38	1.89	6.23	1.59	1.877	12	0.085	0.51
Mathematics	16.15	5.83	18.69	4.46	2.395	12	0.034*	0.51
Impact on Learning of Self and Others	6.31	1.80	7.77	2.09	2.502	12	0.028*	0.78

Hedges g analysis indicates that the intervention had a small effect on Self Esteem, Confidence and Emotional Wellbeing (g=0.17), Learning and Social Behavioural Skills (g=0.2), and a moderate yet not clinically significant effect on Spelling (g=0.51).

Further moderate effects were observed post-intervention on Balance and Coordination (g=0.59; p=0.005), Gross and Fine Motor Coordination (g=0.61; p=0.035), Reading (g=0.79, p=0.01), Mathematics (g=0.51; p=0.034) and Impact on the Learning of themselves and others (g=0.78; p=0.028). Finally, a large and significant positive effect was observed on the teacher's perceptions of pupil mathematics ability from pre- to post-intervention (g=1.28; p=0.0002). Again, as with the t-test scores above all of these effect size results can be considered clinically relevant in the field of education and pupil development, given that any intervention which can be seen to develop and improve pupils in these essential developmental areas is relevant.

4.4 Correlational Data

Correlational data is summarised below in table 4.4. There was a positive and significant relationship (r=0.75; p=0.003) between the highest level of balance exercise reached and the improvement observed in teacher's assessment of balance ability, and between the highest level of eye tracking reached and the improvement in teacher assessment of reading ability (rs=0.628; p=0.022). All other correlations investigated were insignificant.

Table 4.4 - Correlational Analysis Results

Relationship Measured	Rs	p
Percentage Attendance of the Intervention and Number of CfE Categories Improved	-0.07	0.800
Number of Very Easy Sessions and Number of CfE Categories Improved	0.41	0.160
Highest Level Reached in Balance Exercises and Improvement in Balance Score	0.75	0.003**
Highest Level Reached in Coordination and Improvement in Gross/Fine Motor Skill Score	0.426	0.129
Highest Level Reached in Eye Tracking and Improvement in Reading Score	0.628	0.020*
Highest Level Reached in Eye Tracking and Improvement in Spelling Score	0.346	0.247
Highest Level Reached in Eye Tracking and Improvement in Writing Score	-0.1	0.670
Highest Level Reached in Coordination and Improvement in Mathematics Score	0.604	0.02*

4.5 – Cost Effectiveness

ICER values were calculated for variables in which there was a significant improvement from pre- to post-intervention, using the figure identified in the methods section above as £1,502.19 per pupil. These ratios are summarised below in table 4.5

Table 4.5 – Incremental cost effectiveness ratios Summary

Developmental Variable	**Hedges G**	**ICER**
Balance and Coordination	0.97	£2,546.08
Gross and Fine Motor Control	0.61	£2,462.61
Writing	1.28	£1,173.59
Mathematics	0.58	£2,945.47
Overall Literacy	0.86	£1,451.39
Impact on Learning of Self and Others	0.78	£1,925.88
Executive Functioning	0.97	£1,548.65

5.0 Discussion

The aim of this research was to investigate the influence of a physical literacy intervention delivered using digital technology in Scottish primary school settings. The outcomes of interest were physical literacy and academic attainment of children, as well as the cost effectiveness of the intervention. The results presented indicate that participation in the STEP programme improved pupil's academic attainment progress in writing, listening and talking, and health and wellbeing. Furthermore, these improvements were accompanied by positive changes in social and behavioural skills perceived to be important amongst developing primary school aged children, and teacher-perceived improvements in mathematics and reading. These findings will now be discussed below broken down by the classification of effect they had on the pupil's overall attainment and development.

5.1 Literacy Attainment

The results of the present study estimated that participants in the STEP Intervention had greater odds of moving up a teacher assessment banding within the CfE framework for Reading, compared to those in the control (OR=5.6), however this estimate was not statistically significant. A potential reason for this lack of significance the use of a small sample size, which could have limited the ability of the measure to pick up subtle changes (Rutt, 2015). Another is the limited sensitivity of the measure used. A pupil is considered to be "well below expected attainment," if they are more than 6 months behind the expected level for their chronological age, and "below expected attainment" if they are 0-6 months behind. As a result of these bandings, it is possible that a pupil who was significantly behind could improve their attainment by several months, without moving up a banding. (Harlen et al., 2002). This assertion is supported by the finding that teacher's assessment of the pupils reading improvements collected via the pupil questionnaire demonstrated a positive and significant improvement (g=0.79). This effect is comparably larger than those observed in traditional 1-1 interventions delivered to comparable pupils such as Switch on Reading (d=0.24; Gorard, Siddiqui and See, 2015c), Catch Up Literacy (d=0.12; Rutt, 2015) and Reach (d=0.34; Sibieta, 2016). In addition caution should be taken examining teacher assessed position within the CfE bandings due to the potential for limited inter-rater reliability the measure possesses.

A potential reason for the perceived improvement in reading ability is the strengthening of the muscles of the eye. Physiological elements of reading proficiency such as visual fixation, accommodation, binocular fusion saccades and convergence have been acknowledged in a range of literature to be improved upon by exercises strengthening the muscles of the eye, known as oculomotor visual therapy (Hussaindeen et al., 2018; Jang et al., 2017; Goldstand, Koslowe and Parush, 2005; Nazir and Nabeel, 2018). The theory that strengthening of the eye muscles played a role in the improvement of reading proficiency is further supported by the completion of an average of 14.5 hours of eye tracking exercises by each pupil throughout the intervention period, as well as the moderate-strong correlation found between the level of eye tracking STEP exercise attained and the improvement in teacher-assessed reading ability (r=0.6), however considering the significant financial cost of eye tracking measurement equipment, it was not possible within this project to quantitatively track any changes, and therefore it should be a priority of any further research to establish the specific impact of the intervention on this parameter. Given the apparent gap in efficiency between the current intervention and those discussed above (Gorard, Siddiqui and See, 2015c; Rutt, 2015; Sibieta, 2016) in which dedicated time was not assigned to the development of ocular motor muscle development, it could be concluded that the ability of STEP to train muscles is a factor determining its efficacy.

Another potential justification for the perceived improvement in reading is the proposed association between reading ability and physical activity. It has been suggested that physical activity breaks throughout the day enhances brain activity by increasing blood supply, promoting the development of new neurones (Hernandez, 2007). In addition, physical activity improves information retention (Jensen, 2000) and specifically reading ability (Berg, Earney and Wallert, 2015). This is further supported by a systematic review and meta-analysis of 37 studies (Watson et al., 2017) that short physical activity breaks throughout the school day improve reading attainment. Specifically, a series of studies focussing on reading observed mixed impact (Howie, Schatz and Pate, 2015; Uhrich and Swalm, 2007; Erwin, Fedewa and Ahn, 2012; Fedewa et al., 2015; McCrady-Spitzer et al., 2015; Mullender-Wijnsma et al., 2015;2016; Riley et al., 2015; Katz et al., 2010; Reed et al., 2010). A potential reason for the variance in reported effect comes from the length and frequency of interventions, as well as the modes of assessment used. Studies shorter than one year which used national standardised assessment methods (Riley et al., 2015; Katz et al., 2010; Reed et al., 2010; Mullender-Wjinsma et al., 2016) reported insignificant findings, where those using progression-based assessment identified significant and positive impacts. In addition, studies which lasted 1 year or more, with sessions twice per day of a minimum of 10 minutes duration (Watson et al., 2017) has the largest impact, most comparable to the current research. This comparability would suggest that these features could have been a key factor in the success of the current research.

Being in the STEP Intervention group versus the control group significantly increases the odds of moving up a teacher assessment banding within the CfE framework for Writing (OR=6.7). This was further backed up by the teacher completed pupil questionnaires, in which perceived writing ability improved significantly. One possible reason for the positive impact of STEP on pupils writing competency is the focus on fine motor coordination. Pupils on the STEP Programme completed 164-185 exercises focussing on gross and fine coordination skills, with each pupil completing an average of 13.4 hours of these exercises throughout the intervention. Fine motor precision has been highlighted in cross sectional research to have a positive impact on the handwriting legibility (r=0.78), as well as a negative correlation with time take to complete a standardised writing assessment (r=-0.68) in pupils similar to those involved in the current research (Seo, 2018). Moreover, pupils of a comparable age to those in the current research were found to attain significant improvement in recognised handwriting skills such as in hand manipulation (d=1.51), position in space (d=0.67), and speed and dexterity (d=0.58), following motor coordination delivered by trained occupational therapists in a comparable methodology to the STEP intervention (6x15 minute sessions weekly; Case-Smith, 2002). However, caution must be taken when comparing the findings of both Seo's and Case-Smith's (2002) research to those of the current study, as a result of the differing data collection measures. In each of the studies discussed above handwriting was assessed using tests such as the Bruininks-Ostertsky Test (1978), Developmental Test of Visual Motor Integration (Beery, 1989) and the Test of Visual Perceptual Skills (Gardner, 1982) which are widely acknowledged to be valid and reliable assessment protocols (Klien et al., 2011). In contrast, such measurement tools were unavailable within the current research, and as such it is challenging to effectively compare these results to the teacher-impressions attained from the pupil questionnaire and academic attainment results. Despite these challenges however, it would appear that a major factor determining the impact of the STEP intervention from the perspective of pupils writing attainment is its inclusion of a focus on fine motor coordination.

Participation in the STEP intervention significantly increased the odds ratio of improvement in teacher perceived attainment of Listening and Talking competency (OR=11.278). Comparable interventions have observed mixed results, with some attaining no changes (d=-0.05; King and Kasim, 2015), some observing insignificant changes (d=0.03-0.24; Styles, Clarkson and Fowler, 2014; Gorard, Siddiqui and See, 2015a) and some with a significant and positive impact (d=0.43; Merrel and Kasim, 2015). A potential reason for the variation in effect in this regard comes from the methodological variances between the studies, with interventions lasting between 10 and 20 weeks, rather than the full academic year that STEP ran.

Similarly, to the reading improvements observed, a possible justification for this finding comes from the physical nature of the exercises completed throughout the STEP intervention. The positive relationship between physical activity levels and better communicative skills has been acknowledged in a range of population groups, including pre-school children (Akamoglu et al., 2019), primary school children and adolescents (Strauss et al., 2001), and children with additional support needs (Healy et al., 2018; Sowa & Meulenbroek, 2012). One of the main reasons proposed in literature (Chan, Deng and Yang, 2009) for this commonly observed effect is the increased social interaction gained through the delivery of such physical activity interventions. This increased social contact is significant, because children who have limited social and communicative skills will most likely benefit from this dedicated 1-1 time where they can express themselves more fully and develop the communicative skills to then take back and apply in larger groups (Chan, Deng and Yang, 2009). Given that the average STEP pupil participated in 959.3 sessions, they have received approximately 159.9 hours of one-to-one time with an adult, and the positive impact this is suggested to have on communicative skills, this can be considered a key element of the STEP programme when determining its effectiveness. Caution must be taken when interpreting these findings, however, because of the use of teacher opinion-based assessment. The use of such a measurement protocol has been suggested to have variable validity in this setting, because of the variability in how teachers may perceive certain communicative behaviours (Arbeau & Coplan, 2007). For example, it has been suggested that a teacher may consider a particularly communicative and outgoing pupil to be either outgoing and confident or rude and disrespectful, and that should a pupil be quiet and withdrawn that this may be seen as either respectful or an indication of shyness and a fear of public speaking (Bosacki, Rose-Krasnor and Coplan, 2014). Despite this need for caution, such a finding of the efficacy of the STEP intervention from a listening and talking perspective may be significant, given the suggested impact that improved communication skills can have on a pupil’s ability to feel accepted in groups, and to take advantage of developmental opportunities in later educational life (Rubin et al., 2009).

5.2 Numeracy Attainment

Participation in the STEP intervention group led to a slight increase in the odds of improving attainment of mental (OR=0.98) and general mathematics (OR=0.01) when compared to the control group, although these differences were not statistically significant. Similarly, to the assessment of reading progression, however, caution must be taken when interpreting this finding given the limited sensitivity of the measure and previously acknowledged challenges that come with national standardised assessment structures in interventions lasting up to one year in primary school settings (Watson et al., 2017). When considering the t-test data attained from the pupil questionnaires there was a significant improvement in perceived mathematical ability amongst intervention group pupils (g=0.051). This perceived improvement is slightly higher in nature than those observed via more traditional classroom-based interventions such as Number Rockets (d=0.34; Rolfhus et al., 2012), Every Child Counts (d=0.33; Torgersen et al., 2013) and Catch-Up Numeracy (d=0.21; Coleman, 2014). It is also a comparable improvement to those attained in other interventions in which digital technology was used to deliver sessions and content such as Tom's Rescue (d=1.45; de Castro et al., 2014), GraphoGame Math (d=1.03; Salminen et al., 2015) and The Number Race (d=0.8; Wilson et al., 2008), suggesting that this may have been a key characteristic of the STEP intervention determining its ability to deliver positive results. There are a number of reasons why the STEP intervention may have had a positive impact on mathematical attainment. Firstly, it is possible that the increase in physical activity that comes with more enrolment in the programme is likely to have had a positive impact. This follows a number of interventional studies demonstrating significant impact on mathematical competency following physical activity interventions (Gao et al., 2013; Telford et al., 2012; Donnelly and Lambourne, 2011; Ericsson, 2008), as well as several peer reviewed systematic reviews indicating that this is where the largest impact of physical activity on academic performance lies (Fedewa and Ahn, 2011; Singh et al., 2018; Alvarez-Bueno et al., 2017; Donnelly et al., 2016). The precise mechanisms by which physical activity elicits these positive impacts, however, are still unclear (Singh et al., 2018) and given that it was not possible to explore this in great detail within this research to further investigate in this area, caution must be taken when seeking to identify which physical elements of the current intervention led to improvements observed.

Another potential reason for the improvements in maths observed by class teachers comes from the focus on gross and fine motor coordination. As discussed in section 2.4.2, a number of studies have highlighted a positive correlation between both gross and fine motor competency and mathematical attainment in primary school pupils (r=0.15-0.71; Cameron et al., 2012; Pagani and Messier, 2012; Pagani et al., 2010; Son and Meisels, 2006; Suggate, Stoeger and Fischer, 2017; Aadland et al., 2017b; Cameron et al., 2012; Haapala et al., 2014; Jaakola et al., 2015; Kurdek and Sinclair, 2001; Magistro, Bardaglio and Rabagletti, 2015; Pagani and Messier, 2012; Son and Meisels, 2006; Xiang et al., 2017). One proposed justification for these observations in comparable literature is that the improvement of motor coordination has a direct impact by supporting the use of math manipulatives (Hudson, Ballou and Willoughby, 2020) which are commonly used within pupils of this age to aid in the leaning or mathematic technique, particularly when these pupils are behind academically. This assertion is supported by the finding of a direct correlation between the highest level of coordination achieved by the STEP intervention pupils and their corresponding improvement in teacher assessed numeracy ability (r=0.6). Another suggestion is that the improvement of gross and fine motor coordination has an indirect effect, by improving the executive functioning of a pupils, widely acknowledged to play a key role in readiness to learn key academic skills including numeracy (McClelland & Cameron, 2019). However, given that the STEP pupils also observed a significant improvement in teacher assessed executive functioning it was not possible within this research to distinguish between these two possible justifications of improvement. Resultingly, this should be an element of consideration in future research in this area to provide a more accurate overview of the mechanisms by which the STEP programme works.

5.3 Impact on Psychology, Health and Wellbeing

The odds ratio data indicated a significant impact of the STEP intervention, with pupils participating 67.7 times more likely to move up banding within the teacher assessed CFE attainment structure (OR=67.7). The most likely reason for this is the inclusion in the Health and Wellbeing CfE banding of Balance and Control, coordination and fluency, rhythm and timing and gross and fine motor skill competencies (Scottish Government, 2018), and the close focus on each of these within the STEP exercises carried out as part of the intervention. The finding is comparable with numerous studies of similar population groups which have established the positive effect of daily physical activity interventions carried out within school on physical literacy outcomes of children, as highlighted in meta-analysis by (Watson et al., 2017). Another possible reason for the improvement in teacher perceived health and wellbeing was the impact the STEP programme had on the pupil’s motivation and confidence to participate in physical activity. In addition, this improvement could be attributable to the influence the intervention had on the pupil's ability to appreciate the value of such physical activity, all of which are also included in the framework presented within the CfE structure (Scottish Government, 2018). A systematic review of physical activity interventions delivered in primary and secondary school settings (Demetriou and Honer, 2012) highlighted that in 42 studies a positive impact was observed in physical activity behaviours following the intervention period, with attitude to physical activity, motivation to participate, and appreciation of physical activity importance highlighted as the key variables (Demetriou and Honer, 2012). A strength of a number of these studies is their use of pedometers to interpret physical activity, given as discussed in section 2.1 that they are a valid measurement strategy which minimises the risk and severity of human reporting error. The pupils within this intervention observed a slight increase in teacher perceived pupil confidence, self-esteem, and emotional wellbeing although this was not significant. Furthermore, caution must be taken when interpreting this finding, given that the questions were not focussed on physical activity behaviours. Resultingly, it was beyond the scope of this research to establish if any effect existed on the pupils' perceptions of physical activity, or their ability and motivation to participate in it given the lack of any assessment of physical activity level within the assessment protocol.

Furthermore, given the suggestion by Whitehead (2013) as well as Robinson and Randall (2017) that any attempt to assess physical literacy, its development, and indeed its impact in any context should include reference to and evidence of assessment of the psychological variables discussed above, it was not possible within the current research to demonstrate the extent to which the physical literacy of the participants was impacted by the intervention. Taking this into consideration, any future assessments of the STEP intervention would benefit from inclusion of relevant assessment protocols for such evaluation, such as the Canadian Assessment of Physical Literacy (Longmuir et al., 2018) which is widely acknowledged within the physical literacy area as a valid assessment.

5.4 Impact on Learning and Social Behavioural Skills

Pupils in the intervention group observed a small but not statistically significant improvement in learning and social behavioural skills, as well as a significant impact on the learning of themselves and others. While not statistically significant, this finding that learning and social behaviour was positively impacted upon is in agreement with numerous studies of physical activity in primary and secondary school settings, which have found positive relationships between physical activity and making friends (Bean and Forneris, 2016; Bignold, 2013; Draper and Coalter, 2016; Gordon, Jacobs and Wright, 2016), creating meaningful relationships (Camire, Trudel and Forneris, 2009), communication skills (Fraser-Thomas and Cote, 2009; Harrist and Witt, 2015) and prosocial behaviours such as empathy and respect (Driska et al., 2017; Bean, Whitley and Gould, 2014; Burnett, 2015; Camire and Trudel, 2010; Vierimaa et al., 2017). It is likely that the difference in outcome between these papers and the current research comes from the type of activity carried out, with all of the studies above focusing on group interventions rather than one-to-one interactions. If current, the implication from this for future practise would be that if the primary objective of the intervention is to deliver better social skill development, group activity may be preferrable to a 1-1 alternative. Group interaction is considered to be more likely to improve social skills in children, given the requirement to interact in this manner to effectively participate (Opstoel et al., 2020). Other studies, however, have also demonstrated a positive effect of physical activity interventions delivered 1-1 and in small groups on the on-task behaviour of children within lessons (Mahar et al., 2006; Riley et al., 2015; Howie, Beets and Pate, 2014; Bailey and DiPerna, 2015; Goh et al., 2016; Grieco et al., 2016) indicating that further research is warranted to establish the extent and nature of impact that STEP can produce on classroom and social behaviours. It is a possibility that pupils classroom behaviour improved as a result of having the incentive of the STEP exercise sessions to behave for. This has been seen in a comparable study (Lubans, Foster and Biddle, 2008) as an example of an extrinsic motivator producing positive impact, although it cannot be definitively confirmed that this is the case here, given that no questions to this effect were put to either the pupils or their teachers.

In addition, it was observed that the pupils within the STEP intervention improved their teacher-assessed executive functioning significantly. A number of comparable studies in primary school settings have observed positive impact on executive function when carrying out digital interventions (Holmes, Gathercole and Dunning, 2009; Klingberg et al., 2005; Bergman-Nutley et al., 2011), exercise (Uhrich and Swalm, 2007; Budde et al., 2008). Importantly, movements which were rhythmical and repetitive in nature in a similar manner to many of the STEP intervention movements, such as martial arts, dance and yoga yielded some of the most significant improvements (Manjunath and Telles, 2001; Lakes and Hoyt 2004). Considering a number of the STEP intervention exercises contain similar elements, these findings would suggest that these are a key component of the programme when developing executive function. In addition, it has been found in comparable intervention research that these improvements were sustained after the intervention period (6 month follow up; Holmes et al., 2010; Holmes, Gathercole and Dunning, 2009), although given the lack of a post intervention re-test in the current research, it was not possible to establish if this sustained effect is present here.

Furthermore, given the correlation between executive function and early stage numeracy (r^2=0.22-0.61; Agostino, Johnson and Pascual-Leone, 2010; Andersen et al., 2008; Bull and Scerif, 2001; Hecht, Close and Santisi, 2003; Kroesbergen et al., 2009) and literacy, as highlighted in a meta-analysis of 29 comparable studies (r^2=0.33-0.39; Follmer, 2017), as well as the observed improvements in the current research it could be suggested that the improvements elicited in executive function are a key reason for the overall success of the programme. Caution must be taken when considering the comparability of the current research, however, because of the lack of a previously validated assessment of executive function and the challenges that frequently come with opinion bias in teacher-opinion assessment (Harlen et al., 2002). That being said, considering the proposal that the correlation between executive functions and numeracy and literacy continue into early adulthood and beyond (Follmer et al., 2017; Cragg and Gilmore, 2014) this finding that STEP delivered an improvement can be considered significant, and warrants further investigation in any future research.

5.5 Cost Effectiveness Analysis

The current research estimated there was an ICER of £1,451.39 (g=0.86) for literacy, suggesting that for every unit increase in the literacy outcome, the cost to the school would be £1,451.39. This is comparable to that observed in other studies of effectiveness finding significant positive effect such as Reach (d=0.34; ICER=£1,429.41; Sibieta, 2016), and substantively more effective than others such as Switch on Reading (d=0.24; ICER=£2,612.50; Gorard, Siddiqui and See, 2015c) and Perry Beeches (d=0.36; ICER=£3,888.89; Lord et al., 2015). This finding is substantial, given the proposal by several authors (Jones et al., 2006; Karoly et al., 2005; Borman and Hewes, 2002; Hummel-Rossi and Ashdown, 2010) that there are several severe consequences of children failing to reach expected literacy levels in childhood. These include increased rates of future poverty, unemployment, and crime as adults, as well as antisocial behaviour and truancy as adolescence, all of which come with significant expense to the government (Hummel-Rossi and Ashdown, 2010). This importance is further supported by the findings of a comparable literacy intervention (Reading Recovery; Jones et al., 2005) who discovered a comparable effect on literacy (d=0.87; p=0.05) meant that for every £1 spent on the intervention and its delivery, approximately £14.81 - £17.56 were saved as a result of the improvements yielded. Furthermore, this outcome was achieved at an approximate value of £2,500 per pupil, meaning that the current study would suggest STEP would yield further cost benefit.

With regards to numeracy attainment, according to the current research for every unit of improvement in numeracy score there would be an attributable cost of £2,945.47 (g=0.58). There is an acknowledged gap in literature with regards to the cost effectiveness of numeracy interventions (Levin and McEwan, 2001; Levin & Belfield, 2015; Clarke et al., 2020) and despite several studies demonstrating significant impacts (Wilson et al., 2008; Salminen et al., 2015; de Castro et al., 2014) few complete the necessary cost analysis to provide a comparable ICER. Where comparisons can be drawn, the current research can be seen to be more expensive per unit of effectiveness to similar levels of effectiveness to interventions such as ROOTS (g=0.81; ICER= £1,896.71; Clarke et al., 2016), Mathematics Recovery (d=1.14, ICER= £1,867.71; Smith et al., 2013) and Number Rockets (d=0.34; ICER= £500; Rolfhus et al., 2012), suggesting that if numeracy attainment is the leading motivator for seeking out an intervention, there may be better alternatives to the STEP Programme. On the other hand, the impact of early failure to attain in mathematics at the expected level on long term academic and employment potential is significant (Morgan et al., 2016) and the gap between those attaining and those who are not in mathematics widens over time (Morgan et al., 2019). This, and the suggestion that the most cost-effective intervention of those compared was less effective, means that there may be situations in which implementation of the STEP intervention is advisable. In addition, it has been highlighted in cost effectiveness research surrounding mathematics that proximity of the intervention to the assessment measure should be considered when comparing interventions, as many are so close in nature that they can exaggerate the suggested effects of the intervention (Clarke et al., 2016).

Finally, from a behavioural point of view, the STEP intervention yielded an ICER of £1,925.88 when examining the impact on learning of the pupil and those around them, as well as £1,548.65 (g=0.78) for executive functioning (g=0.97). While there are few studies to which these findings can be compared, the Incredible Years Programme (Olchowski, Foster and Webster-Stratton, 2007) found an impact on negative pupil behaviour (d=0.53) was attained at an ICER of £1,548.65, suggesting the current research is similar in impact to a well renowned intervention (Jones et al., 2007; 2008).

A key component of cost effectiveness analyses is to compare estimates across intervention strategies (McEwan and Levin, 2001). In the event of literacy attainment being a primary objective, the current research suggests that STEP may be a preferable option that provides high-cost effectiveness. In contrast, where numeracy is the main objective there are alternative interventions that may provide more cost-effective improvements. However, when considering the programme holistically, the current research suggests that the STEP intervention can impact substantively on both of these academic components as well as classroom behaviour, executive function, and physical components such as balance and coordination. For this reason, it is important to consider the wider associated benefits the STEP intervention may produce for the pupil when comparing its suitability to that of other interventions in primary school settings. On the other hand, given that long term impact and effectiveness of the improvements observed were not monitored as part of this research, and the differences in measures used to record both intervention and cost effectiveness, comparisons of the current findings to that of any other research must be done cautiously and with an appreciation for the need for further evaluation of the STEP intervention.

6.0 Conclusion

It was the objective of the current research to further the knowledge around the potential of a physical literacy intervention delivered using digital technology to impact on the learning, behavioural and physical outcomes of the children participating and interacting with the intervention and its progress through the digital platform. The findings further the belief within comparable studies that interventions involving regular physical activity breaks from lessons can have significant benefits on the academic attainment of children, with particularly strong impacts evident for reading, writing and numeracy competencies as well as executive function. The potential implications of this finding are reinforced by the assertion in a range of peer reviewed literature that failing to attain at expected level in primary school can have long lasting and severe implications for pupils, ranging from a widening gap in academic ability to their peers as they progress through school life to increased rates of unemployment, antisocial behaviour, and ill health. In addition, the findings of this research suggest that the STEP intervention was capable of eliciting significant improvements in participants physical attributes such as balance and eye tracking as well as both gross and fine motor control. The extent to which a child can competently demonstrate these attributes has been suggested to impact significantly on the chance that they will participate in physical activity at the recommended level (Demetriou and Honer, 2012) as well as on their probability of continuing to do so throughout their adult life (McKenzie et al., 2002). Resultingly, it is a strength of the STEP physical literacy intervention that it produced these results, and further studies should seek to examine further how these were attained in more detail, and with a longitudinal follow up to assess the impact that they have on motivation to take part in physical activity and appreciation of its importance as participants get older and begin to prioritise their own behaviours.

It was a secondary objective of the current research to evaluate the cost effectiveness of the STEP intervention. The findings above suggest that when compared to alternative classroom-based interventions for literacy, STEP can provide comparable or slightly better value for money, particularly in the case of writing ability. This, in combination with the finding that the STEP intervention can provide a significant positive impact on physical capabilities of the pupils involved suggests that it may be a worthwhile investment for schools at which the identified academic need is for an improvement in literacy. On the other hand, the findings above also suggest that while numeracy attainment can be positively impacted upon by the STEP intervention, this was not as cost effective as other interventions, suggesting that if increased numeracy attainment is the driving force of need within the school an alternative intervention may be more beneficial.

While these findings are important, there are a number of limitations to the current research which must be acknowledged when considering the implications for future practise. Firstly, it is a limitation of this research that pupils could not be evaluated at the end of the two-year intervention and longitudinally after the intervention was complete. This lack of follow up evaluation means that the findings of this study are only the midpoint (one year) of the intervention, and resultingly fail to account for the full efficacy of the programme. Another limitation is that of the limited sensitivity of the measures used within the research, which may have resulted in false positive results which are really a result of the pupils growing older and developing as they would have regardless of any intervention. As such, further investigations of the STEP intervention should seek to include more sensitive measurement, such as having a control group of non-intervention pupils measured on the pupil questionnaire as well as the intervention group, and the previously mentioned Canadian Assessment of Physical Literacy (Longmuir et al., 2018). Another limitation of the current research is its lack of a measure of psychological variables associated with physical activity behaviour, such as that included within the CAPL (Longmuir et al., 2018). This is significant as according to the work of Whitehead (2013) in order to measure physical literacy accurately and holistically it is essential to capture this aspect, and as such means the research was unable to assess the extent to which the STEP physical literacy intervention impacts upon physical literacy.

A further limitation of the study is its small sample size and gender imbalance. This imbalance and limited sample negatively impact the generalisability of findings as well as the sensitivity of some of the statistical measures used, and as discussed throughout section 5 mean that caution must be taken when drawing conclusions from the findings of the study. Moreover, while age matching took place to an extent with the Intervention and control data for the academic attainment scores, the lack of an age-specific control group for all other measures limited the generalisbility of the findings across the age range STEP is for. With all pupils assessed between the ages of 7 and 9, the 9-13 years age group currently are still untested and so findings of the above research cannot be confidently applied to this range.

Finally, as mentioned above it was not possible within this research for ethical and logistical reasons to have a control group from which to base a randomised control trial. This would have further contextualised any proposed findings of effect within the intervention and should be considered for future research in the field.

In addition to the limitations noted above however, there are some considerable strengths to this piece or research. Firstly, it has captured the interventional activity of pupils across a full academic year, observing the effects of an intervention delivered for an average of 959 sessions (160 hours) on 25 measures of pupil development and attainment. The current research has also been able to suggest approximate cost effectiveness of the intervention protocol researched, which allows for readers to appreciate how it compares to alternative interventions and make informed decisions regarding the measures that would be most suited for their pupils educational and developmental needs. Moreover, the current project adds to the bodies of research suggesting that both digitally delivered interventions, and those seeking to use physical movement to enhance academic attainment, can produce significant results in primary school educational settings.

In conclusion, the current research demonstrates that the STEP intervention possesses the potential to produce significant impact on the educational, behavioural, and physical capabilities of pupils who participate in a cost-effective way. However, further research is warranted to better understand how these improvements are achieved, how they will manifest over time, and to better link them to pre-existing concepts such as that of physical literacy.

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8.0 Appendices

Appendix 1 – STEP Pupil Questionnaire

Developmental Items

Item		Score
1	Shows pride in his/her work and achievements	
2	Is able to catch and throw a ball	
3	Engages in and is open to learning opportunities	
4	Dresses independently (including buttons, zips, shoe laces)	
5	Recalls the spelling of a range of high frequency words	
6	Sustains concentration for appropriate time on learning tasks	
7	Engages willingly with books and reading activities	
8	Shows a developing knowledge of number facts and relationships	
9	Attempts written tasks independently	
10	Successfully joins in and cooperates with organised games e.g. follows rules	

11	Listens when spoken to directly by an adult	
12	Engages in fine motor activities willingly e.g. construction, art	
13	Copes with disappointment e.g. not being chosen	
14	Uses appropriate decoding skills with success	
15	Shows a developing understanding of addition and subtraction	
16	Complies with adult requests , is biddible	
17	Seeks reassurance appropriately	
18	Commences tasks within an appropriate time frame (including written tasks)	
19	Has good posture when sitting and walking	
20	Makes phonically plausible attempts at unknown spellings	
21	Remains reasonably quiet when the class is addressed by the teacher	
22	Seeks attention appropriately e.g. in terms of quantity and through positive means	
23	Remains within the teaching area for whole lessons	
24	Organises own belongings and equipment e.g. packs school bag, collects equipment for a task	
25	Uses an appropriate pencil grip (tripod grasp)	

26	Reads without needing to use a finger or guide to aid tracking	
27	Shows a developing understanding of multiplication and division	
28	Sits without fidgeting or fiddling	
29	Communicates effectively with peers	
30	Carries out a series of instructions successfully	
31	Walks and runs in a coordinated fashion	
32	Is willing to read aloud with a small group of peers present	
33	Attempts classroom tasks independently	
34	Colours and cuts neatly in relation to outlines	
35	Remembers what he/she wants to say or do e.g. having held up hand to answer a question	
36	Demonstrates a developing understanding of fractions (decimals, percentages), money and measure	
37	Produces an appropriate quantity of written work	
38	Understands what she/he has read	
39	Is able to self regulate behaviour e.g. considering consequences before acting	

40	Copes with difficult/unfamiliar situations e.g. will continue to work at a challenging task	
41	Recalls familiar sequences e.g. days of the week, months of the year, alphabet, simples times tables	
42	Shows a developing knowledge of shape, position and movement	
43	Is able to copy from the board/a book with accuracy and sufficient speed	
44	Joins in physical activities willingly	
45	Demonstrates growing fluency in reading	
46	Handwriting is controlled and legible	
47	Makes eye contact with known adults in school	
48	Is developing data handling skills	
49	Shows awareness of the location of objects and people when moving around / positioning him/herself	
50	Is able to organise and structure pieces of written work	
51	Expresses emotions appropriately	
52	Shows good sitting posture when writing and does not suffer discomfort e.g. in hand or neck	
53	Is able to carry out appropriate mental maths tasks	

54	Accepts praise appropriately	
55	Carries out homework tasks/shows interest in learning beyond the lesson	
56	Makes and maintains reciprocal friendships	