Hegartymaths: gimmick or game changer?

by

Athanasios Gidaropoulos

Canterbury Christ Church University

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I dedicate this thesis to my mother;
you will always be my first teacher and the one
who instilled in me a love of learning.

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Abstract

This research examines the effectiveness of Hegartymaths, an online platform comprised of mathematical instructional video tutorials and quizzes used in approximately a third of mainstream secondary schools in England.

The study employed mixed methods from an objectivist epistemological standpoint and used quasi-experiments to assess how schools who use Hegartymaths compare with ones that do not, as well as exploring how schools' implementation of Hegartymaths impacts GCSE performance for the pupils that use it.

In order to explore the impact Hegartymaths on GCSE performance, and specifically on the topics/types of questions which are part of the GCSE, data was collected and cleaned from the Gov.uk website, which publishes KS4 data for all 5,512 schools in England, and the Hegartymaths data team, who shared a snapshot of the big data analytics for 37 United Learning schools (30,501 pupils). A teacher survey, which included 106 responses from United Learning teachers of mathematics, considered which Hegartymaths practices increase its efficacy.

The findings indicate that there are significant and positive relationships between the time spent on Hegartymaths and the performance of students in several categories, and the time spent completing quizzes was more effective than watching the video tutorials. Hegartymaths was seen to be more aligned to questions that test for procedural knowledge, rather than conceptual knowledge, and the schools that were identified to be more successful indicate there seems to be merit in the following practices: setting more Hegartymaths tasks at a time; allowing some topics to be taught solely through Hegartymaths; directing pupils to write notes when watching the tutorials.

The research design and analyses in the study harness the power of big data with learning analytics to contribute to the literature from a methodological point of view, whereas the findings contribute to the limited existing literature on using video tutorials within a blended learning approach.

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Chapter 1: Introduction

Hegartymaths is an online resource that teaches pupils mathematics mainly through instructional video tutorials and quizzes. For a detailed breakdown of the platform's functionality, see Appendix A. Approximately one third of mainstream secondary schools in England use it regularly, which amounts to over one million users at the time of writing. No published research into the efficacy of Hegartymaths is currently available.

There are many studies that look into whether schools are making use of technology in the teaching of mathematics (eg. Bauer and Kenton, 2005; Cuban et al., 2001; Goos and Bennison, 2008). However, the research is particularly limited in terms of how secondary school mathematics teachers use such tools (McCulloch et al., 2018) and what their effect on pupil performance is. For every mathematical topic a student of secondary level wishes to search for, even as early as 2011, there were over one hundred quality instructional videos available to them (Bolliger and Supanakorn, 2011), which could also be used by teachers as supplementary tools for their teaching (Höffler and Leutner, 2007; Bolliger and Supanakorn, 2011). The millions of hits these videos generate prove their popularity (Pell & Croft, 2008), yet the literature on how teachers and students integrate this technology into their mathematics education is very limited (Bray and Tangney, 2017), and there has been little research – if any at all – comparing viewers and non-viewers of instructional videos (Hampton, 2014). In 2018, more than 70 million people used the Khan Academy, known to be the most popular resource around the world for mathematical instructional videos (https://blog.khanacademy.org/2018-in-review-annual-report/#:~:text= Last%20year%20more%20than%2070,lead%20to%20significant%20academic%20results). This American non-profit educational organisation was created in 2008 and, despite its popularity and anecdotal claims regarding the successful impact it has had on students of mathematics (e.g., Noer, 2012), the results of the limited literature on the Khan Academy remain both inconclusive and inconsistent (Hampton, 2014). 'Distance learning' will almost certainly increase in popularity as a topic of interest for current research since the coronavirus pandemic caused schools to close in England in March 2020, whereupon teachers were faced with the unprecedented challenge of providing a remote education for their students. Although the platform was not intended as a response to the pandemic (and nor was this research), for the first three days of the national lockdown pupils across England struggled to access the Hegartymaths website, such was the increase in traffic and therefore the demand for a platform such as this.

As a teacher of mathematics in England since 2006, I knew of the original Hegartymaths website which was launched for free in 2013 and I began using it with my own students when the school I work at paid for a subscription for the new website in 2016. The majority of mathematics teachers I have interacted with have lauded this online platform and the potential benefit of video tutorials was immediately apparent to me, having created my own website - mrgmaths.com - a few years earlier in 2010. Since 2016, the exponential popularity of Hegartymaths led me to look for research that corroborated or questioned these anecdotal claims of so many of my contemporaries. The fact that I could not find any was the inspiration for this study.

I began by asking the simple questions: 'Is Hegartymaths any good?' and 'How can we tell?', which led me to explore various methodologies and methods that could narrow the study to a small subset of the population that uses Hegartymaths, so as to go far deeper into the analysis. Whilst it was very appealing to research this within the context of my school by focusing on pupils in just one of my classes alone, given the country-wide reach that Hegartymaths has, and the fact that a 'big data' study had not been conducted before, I decided that I would adopt a quasi-experimental approach from a post-positivist stance. Another reason for my choice is the potential this has to set the context and pave the way for a smaller scale study (in terms of participants). As an undergraduate student of Engineering, this approach would allow me to use the scientific tools I learnt during that time in designing the quasi-experiments, while also using my fourteen years of experience as a teacher of mathematics to interpret the data in a qualitative way and provide possible insights.

I decided that a post-positivist stance would be most appropriate for this research, for several reasons. Firstly, I accept that there is objective truth, and therefore an objective truth is inherent in Hegartymaths, although I am also aware that separating me (the researcher) from Hegartymaths (the researched object) can only be strived for, as my experience both in the classroom and in using Hegartymaths will influence my research; I pursue objectivity by recognising the effects of bias and stating the limitations of these claims (Robson, 2002). Secondly, as a constructivist practitioner who devotes a lot of time in the classroom to manufacturing social interactions through group work for knowledge creation, I cannot honestly adopt a purely objectivist standpoint, before considering the ethical implications of conducting a 'pure experiment' within an educational setting. Thirdly however, the access I had to the vast amounts of data that I describe next, lent itself well initially to a quantitative project. Research will usually involve numbers, of some sort, at the outset (Gorard, 2001) and this being the first study of Hegartymaths, it seemed appropriate to follow this trend. A large-scale study of this nature also suited a post-positivist approach as interactions are limited in favour of measurements to uncover truth, but the mixed methods approach will still allow me to contribute my knowledge gained from experience to offer different aspects of social reality (Cresswell, 2014; Angouri, 2018).

United Learning is currently the largest multi-academy trust in England, both in terms of schools and pupils, all of which subscribe to Hegartymaths. Working for a United Learning school, I was granted access to vast amounts of secondary data using analytics tracked on Hegartymaths. Data in the public domain was taken from the gov.uk website, and I was fortunate enough to be able to analyse this in conjunction with other sources of data that I had access to, including a breakdown of the exam results of each student from 37 schools, for each of the 212 different questions examined by AQA and 217 questions set by Edexcel. The 'big data' that the Hegartymaths data team granted me access to, were a series of spreadsheets detailing the analytics of each student in these 37 schools for approximately 1000 different Hegartymaths clips; the largest spreadsheet contained 50, 217 rows and 3,493 columns of data, and was over half a gigabyte in size. Using the data from 37 of these mainstream state-funded secondary schools, as well as data provided by the Hegartymaths team, I narrowed down my aim to add to the existing literature by focusing on the following three research questions:

1) *To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE?*
2) *Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?*
3) *How is Hegartymaths used in the most successful schools?*

Due to the limited research available, I decided to review the literature in this study in two parts. In the first part I examine the existing research on technology within education more broadly, before honing into the use of technology within the field of mathematics education research, to establish the context of the online resource Hegartymaths. In the second part, I attempt to blend the knowledge I have from my experience as a practitioner with current literature pertaining to mathematics education so as to identify where Hegartymaths lies. I investigate various philosophical stances in an attempt to find which of these Hegartymaths is most aligned to, before exploring the different types of mathematical knowledge in order to reach definitions of both conceptual and procedural knowledge, to ascertain both the potential and the limitations of how Hegartymaths can be best used to teach these knowledge types to pupils. This part of the Literature Review also concerns itself with common mathematical teaching pedagogies and the common difficulties pupils face across the broad areas of mathematics, to assess if Hegartymaths is more suited to particular strands of mathematics or whether it should be used in conjunction with a specific teaching approach.

The methodology chapter will explain how my research questions came to fruition and the various methodologies I considered in order to conduct the research. I explain that, although I see merit in constructivist epistemology, I elected to use mixed-methods and argue that using the perspective of a post-positivist was the most appropriate approach to take, thereby conducting this research from an objectivist epistemological standpoint. It has also been argued that using both quantitative and qualitative data analyses in a complementary way can harness the techniques of big data and learning analytics (Hoyles and Noss, 2016), which is what I have attempted to do. There is little evidence of any role the mathematics education research community might have played in reaching teachers through initiatives more commonly seen in schools, such as using the tracking system on Hegartymaths, where schools capitalise on the ease of accessing vast amounts of pupil data (Hoyles, 2018). The procedures I used are also documented in each case and the associated limitations these have in relation to the post-positivist paradigm chosen are explained. I conclude the chapter by considering the ethical implications, as well the claims of validity and reliability, of the research.

In the research design chapter I focus on the methods I used within my chosen Methodology to answer my research questions. I define and rationalise the measures I used and describe how I gathered and cleaned the vast amounts of data from multiple sources so as to be able to analyse it. The sampling procedures and statistical tests I needed to carry out before interpreting the data are also explained as well as the process required for me to obtain the results of the survey.

The results of the study are presented in the findings chapter that follows. It begins by analysing the results of the quasi-experiment that compared mainstream secondary schools that use Hegartymaths with schools that do not, based on Attainment and Progress measures of schools overall and within various sub-sections of the schools. Then 37 United Learning secondary schools become the focus, where those same performance measures were analysed in relation to the respective Hegartymaths usage of each school. The last big data findings come from correlations between the amount of marks pupils gained in each of the summer 2019 AQA and Edexcel GCSE mathematics examinations with the amount of time they spent on the associated video tutorials and quizzes on Hegartymaths. Finally, the significant results of the United Learning mathematics teacher survey are interpreted. As with all big data studies of this nature, the empirical work was abundant, and I could only concentrate on including the findings that were the most relevant to my research. This did however include all of the results that were deemed statistically significant.

I then proceed to summarise and explore the analysis of my findings in the discussion chapter. For each research question, I was able to draw on the literature reviewed and my own experience of using Hegartymaths and of teaching mathematics to provide possible explanations and conclusions to the various significant results observed and answer, to an extent, my research questions. The limitations of these conclusions are also reviewed, where I attempt to make recommendations for future research on the subject matter.

The Conclusion to my thesis summarises the findings from this study and its contribution to the existing literature before recommending future research.

Chapter 2: Literature Review Part 1
The use of technology in mathematics education

2.1.1 Introduction

The world has changed radically since formalised schooling was first implemented; perhaps the most pronounced change is that information is now distributed and accessed very differently (Richardson, 2012). This has affected how other institutions operate, but seemingly not schools (Shirky, cited in Richardson, 2012; Ofsted, 2008; Parish, 2019). Whilst the use of technology for teaching is generally encouraged in schools by policy makers, the literature suggests this is focused on how technology can be used to increase student outcomes and improve teaching of a largely unchanged curriculum (Lewis, 2017). In many countries, contemporary policy makers are tasked with developing new curricula in line with rapid technological advancements. In the USA, a 21st century literacies 'charter' was drawn up, one of the permutations of which was "to develop proficiency with the tools of technology" among others pertaining to the 'complex environment' of the information world (NCTE, 2013). However, the integration of digital technology in mathematics teaching remains a challenge (Drijvers, 2019). This review of the literature will argue there is a need for further research into blended learning in the mathematics classroom, specifically in the implementation of technology to enhance traditional modes of teaching through innovative and collaborative use of instructional videos.

Blended learning is the term used to describe the practice of combining technology with face-to-face classroom experiences and this is becoming common practice in education at all levels (LaFee, 2013; Owen and Dunham, 2015), although it should be acknowledged that government recommendations for the use of digital technology in secondary maths curricula in the UK are scant (Parish, 2019). While students commonly express their preference for these increasingly popular (Naccarato and Karakok, 2015; Yang, Lin and Hwang, 2019) technology-enhanced experiences (Mirriahi et al., 2015; Murphy et al. 2014; Weeraratne and Chin, 2018), the vast majority of the literature targets educators of science, the humanities and, in the case of the National Council of Teachers of English, English and language arts. This section of the Literature Review will point to the potential of a blended learning approach to mathematics, as well as the need for more literature concerning the outcomes of integrating video technology into the mathematics classroom.

Over the last twenty years, the amount and variety of technological tools accessible to teachers and students in schools, including within the mathematics classroom, has grown exponentially (Gray et al., 2010; Snyder, de Brey and Dillow, 2016). These digital tools, blended with a fitting pedagogy, have the capacity to address some of the most common issues that arise in mathematics education, including problem-solving and collaborative approaches to teaching and learning (Hoyles, 2016). The internet has played a major role in making these supportive resources universally available and easily accessible (Redmond et al., 2011), which reportedly reduces anxiety for a student working on a task who might need to call on these resources, which in turn deepens their learning (Newby et al., 2006). However, although accessibility might have improved, the majority of mathematics teachers do not use the technology for more than as a simple calculation tool or to display static material, which are unlikely to increase students' proficiency in mathematics by deepening their understanding, stimulating their interests (Cuban, Kirkpatrick and Peck, 2001; Ertmer, 2005) or by encouraging deeper mathematical understanding (Light and Pierson, 2014; Weeraratne and Chin, 2018). This could be the primary reason many claim that the potential of technology is not being realised, both in terms of enhancing the learning experience and improving student outcomes (Geiger, Faragher and Goos, 2010; Lameras and Moumoutzis, 2015; Oates, 2011; Reed, Drijvers and Kirschner, 2010; Selwyn, 2011; Wright, 2010). Further, some research points to how students can often overlook the mathematics elements while using digital modes of learning, and seldom display understanding of concepts or deploy strategies they have learned through their interactions with such tools in their lessons (Geraniou and Mavrikis, 2015).

While a plethora of studies describes whether technology is being used within the mathematics classroom (eg. Bauer and Kenton, 2005; Cuban et al., 2001; Goos and Bennison, 2008), the research on how teachers choose to use these tools is limited, particularly in the case of secondary school mathematics teachers (McCulloch et al., 2018), which will be further explored in this review.

Within the realm of blended learning in mathematics education, a proliferation of instructional videos has been seen to be beneficial - and while they aren't viewed as an absolute remedy or substitute for the teacher - the convenience afforded to students by being able to pause and rewind makes these high-value resources, which may be used as supplementary tools (Höffler and Leutner, 2007; Bolliger and Supanakorn, 2011). Whichever mathematical topic the student wishes to search for on the internet, even by 2011, the result will have contained more than one hundred high quality instructional videos available for the student to select and use (Bolliger and Sopapakorn, 2011); over the last nine years this number will undoubtedly have increased to thousands of internet search results. The teacher also faces the same plethora of instructional videos to choose from, and what is suggested to be critical in this process is the choice of video and how the teacher then chooses to deploy it, once selected (McCulloch et al., 2018; Cheung and Slavin, 2013; Fabian, Topping and Barron, 2016). The research conducted into the factors that influence the decisions made by teachers concerning how they wish to integrate this technology into their teaching is very limited (Bray and Tangney, 2017).

2.1.2 Use of technology in education: Theory vs policy

School has gone virtually unrevised for 150 years, with existing models still chiefly centred on Frederick Taylor's factory type schools (Richardson, 2012). The current education system, which is largely based on standardisation and conformity, is often seen to stifle individuality and creativity (Robinson, 2015).

As such, redefining educational practices - particularly ones that have been entrenched in society for over a hundred years – can be seen as a hugely complex process, and one that inevitably gives rise to a number of tensions. Richardson cites Downes' assertion that "we have to stop thinking of education as something that is delivered to us and instead something we create for ourselves" (Downes, cited in Richardson, 2012). Yet, contrary to this assertion, recently there has been a significant shift back to an emphasis on more traditional modes of teaching. An example of this is that United Learning, one of the largest multi academy trusts in the UK, has stipulated that their schools' teaching and learning policies should aim to be underpinned by the Rosenshine Principles of direct instruction (Rosenshine, 1978), thereby placing high value on knowledge acquisition, which arguably suggests that many educationalists assume that knowledge is in fact fixed and deliverable. Further, the decision-makers at the forefront of education reform appear to subscribe to a worldview that dictates that modern-day, 'connected' young people still need to learn algebra or Shakespeare to succeed in tests, which implies that they purport to know what, when and how every child needs to learn (Richardson, 2012).

One approach to blended learning is mobile learning, defined as "a learning approach using mobile devices and wireless technology anytime and anywhere to achieve a certain learning target in a group" (Hwang and Tsai, 2011; Fua and Hwang, 2018). This is a model that leads to: immediacy and convenience (Kynaslahti, 2003); contextuality (Kearney et al., 2012); accessibility (Parsons and Ryu, 2006); increased flexibility (Sharples et al., 2009); a more dynamic, active, participatory and interactive classroom setting (Overmyer, 2015; Ford, 2015; Yang, Lin and Hwang, 2019); increased autonomy and more opportunities for learners to take responsibility for their own study (Bergmann, Overmyer and Wilie, 2013; Muir, 2017; Li et al., 2015); the creation of learner-generated and personalised experiences for students (Cochrane, 2010; Fabian, Topping and Barron, 2016; Bergmann, Overmyer and Wilie, 2013), and learning contexts wherein the student is less likely to get left behind if they are absent, as lesson content is permanently archived and readily accessible (Bergmann, Overmyer and Wilie, 2013; Muir, 2017). While the aforementioned are viewed as advantages to the mobile learning approach, it should be acknowledged that many are in contention with the principles of direct instruction (DI) – a pedagogical approach that will be looked at in more depth later in this review. Another product of mobile learning that contrasts with the traditional classroom is the metaphor of the 'extended classroom', where learners have increased interactions – and improved interpersonal connections (Van Sickle, 2015; Yang, Lin and Hwang, 2019) - with others through online networks, thereby enhancing the nature of their learning experience as it moves into different 'spaces', such as social, conceptual and physical ones (Newhouse et al., 2006). This informal mode of learning is personalised and collaborative and seen to support inquiry-based learning (Martin and Ertzberger, 2013; Cochrane, 2010).

In direct opposition to an informal, flexible approach, the states of Louisiana, Indiana and Ohio have adopted new education directives, named the Common Core Curriculum, whereby they are using technology to increase the accountability of student learning. They are evaluating teachers against their student test scores and rating schools, among other things the tests were never designed for (Richardson, 2012). Common Core Standards are problematic as these do not acknowledge that learning and literacy are rapidly and radically changing in the internet age. But more alarmingly perhaps, the main thrust for introducing these standards originated in organisations that were not comprised of educators and who were arguably driving this reform because it was a prerequisite for a stimulus grant under the Obama administration's 'Race To The Top' education programmes. An example that illustrates the prioritisation of efficiency and standards over a focus on the whole child is a software package that can supposedly score in excess of ten thousand essays a minute (Hewlett Foundation Automated Assessment prize). In contrast to this somewhat 'closed' use of technology, digital technologies have been shown to promote a more exploratory approach to teaching, through Exploratory Learning Environments (ELEs). Grounded in a constructivist approach, ELEs provide learners with broad, open and collaborative tasks for a range of disciplines, which offers a response to criticisms of the field of educational technology, particularly when it comes to the application of Artificial Intelligence being wedded to an instructional pedagogy (cf. du Boulay, 2019, Wilson and Scott, 2017).

2.1.3 Blended learning in mathematics education

Technology in mathematics education has the capacity to address many of the issues identified above, and it is now claimed that technology has fundamental impact on student success in mathematics (Nepo, 2017; Young, 2018). Technology can: provide students with the opportunities to be exposed to better modelling and visualisation; allow pupils to engage with mathematics in more complex scenarios; shift the learning experience from the conventional classroom to more real-world scenarios (Song, 2014; Fua and Hwang, 2018); construct knowledge, and allow students to gain meaning of learnt knowledge in different contexts (Drijvers et al., 2010; Noss and Hoyles, 1996; Olive et al., 2010). These are the primary reasons that there is a current trend for increasing the priority of blended learning in mathematics education, both in international policy and curricula (National Council of Teachers of Mathematics, 2015; Trouche et al., 2013). This should position problem solving and inquiry at the centre of mathematics in schools and technology should be used to alter the perception of mathematics as a catalogue of procedures and facts that must be memorised (Geiger et al., 2010; Hoyles and Lagrange, 2010). Further, some technology-based interventions – such as Khan Academy – have been shown to sit well alongside existing teaching methods so that teachers do not have to radically overhaul their pedagogical approaches in order to be able to integrate a blended learning model into their practice (Light and Pierson, 2014; Murphy et al. 2014; Trucano, 2014; Weeraratne and Chin, 2018).

Early use of technology within mathematics education exposes diametrically opposed approaches to learning and these, in turn, have led to the creation of widely differing technologies (Sinclair and Jackiw, 2005). For example, early multiple-choice, computer-assisted instruction technology tests restricted expressivity; this behaviourist approach to learning little resembled the technology that Logo (Papert, 1980) had to offer. This was embodied by a constructivist approach to learning, where students were supported to make links between actions and symbolic representations (Olive et al., 2010). Another way to contrast these two approaches is to distinguish between the pragmatic and epistemic value the technology offers the tasks (Artigue, 2002). Computer-assisted instruction - like using a calculator - can be viewed as an efficiency tool that increases the speed and accuracy of computations (pragmatic), whereas students interacting with Logo generates questions about mathematical knowledge and contributes to their understanding of mathematics (epistemic) (Artigue, 2002; Oates, 2011; Olive et al., 2010; Ruthven, Hennessy and Deaney, 2008). The different types of learning that can be achieved through the introduction of technology must be considered before designing tasks accordingly (Sinclair et al., 2010).

The hierarchical way in which mathematics is learnt is at odds with the assumption that content is learnt by pupils at the same rate, because pupils lose engagement if they have not mastered the necessary mathematical knowledge required to access the new content. Classroom teachers therefore face a dilemma regularly: whether to prioritise the individuals who have grasped the concepts and are ready to move on, or to give more time to the pupils who need it before moving on (D'Ambrosio and Borba, 2010). Although one of blended learning's most obvious and attractive advantages is the opportunity it offers for pupils to personalise their learning at their own pace, it has been suggested that technology enhanced learning has not succeeded in achieving this (Chatti et al., 2010). Most of these initiatives currently use technology-push approaches, where content is transferred onto learners in the closed environment of the classroom (Chatti et al., 2010). A recent systematic analysis of 139 studies found that where technology has been integrated into the mathematics classroom, the majority of interventions were classified as 'augmentation', whereby technology was a direct substitute for the teacher and used as part of traditional instructional approaches (Bray and Tangney, 2017).

As mobile learning is considered "learning across multiple contexts, through social and content interactions" (Crompton 2013 p.4), it is arguably undermined when its use is restricted to replacing traditional classroom practice. A student-pull model for learning however, whereby the students discover and navigate the technology themselves, could be the fundamental shift required for a more personalised and dynamic education as opposed to one-size-fits all; the 3P model (personalisation, participation and knowledge-pull) has been recommended to tackle this (Chatti et al. 2010). 'Redefinition' is the term used where technology is deployed to transform tasks through its application; this was the least identified type of current technology integration in the mathematics classroom (Bray and Tangney, 2017). Although the literature argues that redefinition is preferred in order to maximise the use of technology (Noss et al., 2009; Oates, 2011; Olive et al., 2010), this insight suggests that the chosen ways to implement technology in the mathematics classroom is a main reason why the learning experience is not being enhanced as much as it has the perceived potential to (Conneely, Lawlor and Tangney, 2015; Dede, 2010; Hoyles and Lagrange, 2010; Hoyles, 2016; Psycharis et al., 2013), including the potential to increase both extrinsic and intrinsic motivation in pupils (Abeysekera and Dawson, 2015; Muir, 2017).

Cooperative learning in mathematics education is of utmost importance according to empirical research (Jacobs, 1996; Whicker, Bol and Nunnery, 1997). Learning in a group is considered beneficial as the dynamic removes students' frustration by offering a support network and by supplying another source for additional help (Davidson, 1990). The way in which pupils perceive and interact with one another is an aspect of instruction that has been neglected (Roger and Johnson, 1988), which is a concern since learning is situated in practice and all practice is essentially social in nature (Swan and Shea, 2005). Despite the indication that the use of technology is currently largely confined to augmentation of existing classroom practice, the literature illustrates a clear constructivist and social constructivist trend (Bray and Tangney, 2017), which supports the claims made by educators that technology could potentially be used to realise both the student-centred and collaborative pedagogies proposed since the 1960s (Martin and Grudziecki, 2006; Voogt and Pelgrum, 2005; Cochrane, 2010). One recent example is Exploratory Learning Environments (ELEs), that prioritise the growth of conceptual knowledge over procedural knowledge, and which can also support the teacher-facilitator by analysing student responses to suggest, for example, pairings of students for productive discussions on their different solution approaches to a given problem (Mavridikis et al., 2019). This example of ELEs indicates that the classroom environment will not be transformed and developed into one supporting collaboration and exploration with merely an increase in the use of technology (Geiger et al., 2010; Olive et al., 2010).

2.1.4 Instructional videos and the role of the teacher in the mathematics classroom

Khan Academy and Knewton, which pre-date Hegartymaths, are platforms that enable learners to navigate resources, typically high-quality instructional videos, on the internet for STEM (science, technology, engineering and mathematics) subjects that increase understanding as they simultaneously decrease anxiety, and are easy and inexpensive to produce (Papa et al., 2008); students also report enjoying using the Khan Academy platform (Murphy et al., 2014; Fabian, Topping and Barron, 2016).

With that in mind, the bespoke nature of Knewton is a possible solution to accessing the 'right' knowledge without the restrictions of a traditional school curriculum. A teacher could never replicate the level of nuance for each individual child that can be achieved through these videos, which are cited as possibly the most helpful educational tools for those who struggle with mathematics (Höffler and

Leutner, 2007; Bolliger and Supanakorn, 2011). The millions of hits these videos generate indicate their popularity and show that many students turn to these in order to receive the support needed to be successful in mathematics courses around the globe (Pell and Croft, 2008); this is especially significant given the concern around student engagement in mathematics (Skilling, Bo bis and Martin, 2015; Muir, 2017). However, despite the increasing number of students receiving extra help through video platforms, there are still significant numbers of students who are failing these courses (Peterson, Hannushek, and Riddel, 2011) and experts believe that the issues with under-skilled mathematics students will worsen (Morrison, et al., 2011), which is especially true for minorities (Spencer, 2012).

Flipping the classroom is an approach to blended learning that is rising in popularity (Wilson, 2013). Students are set to watch instructional videos in and out of the mathematics classroom to gain basic foundational knowledge before building on this with the guidance of the teacher in class (Lasry, Dugdale and Charles, 2013). The acquisition and recall of knowledge, described by Bloom as a lower level skill, occurs frequently in students' homes, before the analysis, synthesis and application are achieved in conjunction with the teacher in the classroom (Myo-Kyoung et al., 2012). This allows teachers to focus on the higher order thinking skills, such as advanced problem solving, by creating more fruitful problem-based and project-based activities (Degrazia et al., 2001; Rongjin, Yeping and Xiaoya, 2010; O'Brien, Wallach and Mash-Duncan, 2011) in an attempt to provide a relevant mathematics education applicable to the real world (Palfrey and Gasser, 2008).

As discussed, the availability of technology in order to blend this in the mathematics classroom is not the only factor required for an improved mathematics education. The way in which a teacher opts to use the technology through the selection of videos, designing appropriate tasks, or setting up a classroom for an inquiry-focused or collaborative environment, is fundamental (Geiger et al., 2010; Laborde et al., 2006; Olive et al., 2010; Swan, 2005).

Genuine and engaging contexts that require solving through mathematics do not necessarily require technology, although this can have an important role (Confrey et al., 2010; Foster, 2013; Geiger et al., 2010; Hughes and Acedo, 2014; Olive et al., 2010). The teacher's role is to design or select the tasks that use technology carefully, which many argue will only be preferable if the task cannot be solved without technology or will be significantly transformed because of it (Laborde, 2001, 2002; Noss et al., 2009; Oates, 2011; Oldknow, 2009; Olive et al., 2010). One way this can be achieved is to use technology as an instrument of experimentation (Olive et al., 2010). If teachers wish to adopt a task for an enquiry-based learning environment, a fundamental concept they must consider is how open-ended this activity is (Geiger et al., 2010). Another way to use instructional videos is to make use of the opportunity they provide for students to control their own progress through the material (Buteau and Muller, 2006; Olive et al., 2010; Wright, 2010). Again however, it will be ultimately the teacher's decision as to how they can foster and support students' autonomy over their learning, which does have potential to increase their enjoyment and confidence in mathematics (Boaler, 1993; Noss et al., 2009).

Mathematics teachers must change their pedagogical approach if they are to provide a learning experience for pupils that is centred on an inquiry-based, constructivist approach and this is fundamentally dependent on the beliefs the teachers hold, which can be very deep-rooted and hard to change (Donnelly, McGarr, and O'Reilly, 2011; Ertmer and Ottenbreit-Leftwich, 2010; McGarr, 2009). The dominant position the teacher commands in the traditional classroom - whose role it is to transmit knowledge (Conneely et al., 2013; Lameras and Moumoutzis, 2015) - is under threat by the pedagogic approaches complemented by technology (Ertmer and Ottenbreit-Leftwich, 2010; Fullan and Langworthy, 2014; Voogt and Pelgrum, 2005); the integration of technology through "21st century" pedagogies can be seen to undermine this position (Euler, 2011). This has been noted as a reason why teachers accommodate technology in such a way as to make it conform to their current practice (Ertmer and Ottenbreit-Leftwich, 2010; McGarr, 2009; Voogt and Pelgrum, 2005).

2.1.5 Implications, barriers and recommendations

The literature points to a number of reasons to resist moving to blended learning teaching models, one of the more prominent of which being the challenges of training teachers with low digital literacy (Mirriahi et al. 2015, Bergmann and Sams, 2012), in addition to altering their beliefs about teaching and learning (Muir and Geiger, 2016; Yang, Lin and Hwang, 2019). Even before offering assistance and providing professional development for teachers to implement blended learning, creating opportunities for teachers to see the value would be necessary to motivate practitioners to consider integrating this approach (Chen et al. 2010). Apart from repeatedly stressing the benefits for students, another advantage of using blended learning in the form of educational videos is that teachers can develop content and share resources more efficiently. However, some critics fear this could result in standardisation and deprofessionalisation (Bergmann and Sams, 2012).

Barriers to technology integration can be classified as either external or internal (Ertmer, et al., 1999). External barriers, such as student accessibility to computers or the availability of appropriate administrative support, have been largely overcome in England (and in other nations with the resources to equip learners with ready access to technology) with many teaching standards now requiring the use of technology in schools (Bakia et al., 2009; Ertmer, 2005; Means, 2008). The National Centre for Education Statistics found that 95% of teachers had access to one or more computers in their mathematics classroom in the US, which would have been 99% if that were to include teachers' personal computers being brought into the classroom when required (Gray et al., 2010). A further external barrier specific to mathematics is the expense of the licences needed for certain software packages (Washira and Keengwe, 2011).

Yet internal barriers, such as teachers' attitudes and beliefs, have been cited across a range of countries as presenting a greater issue than external barriers to technology integration (Ertmer, 2005; Bauer and Kenton, 2005; Afshari et al., 2009; Kaleli-Yilmaz, 2015; Washira and Keengwe, 2011). Across the USA, secondary school teachers integrate technology into their classrooms less than in primary contexts; technology use in secondary schools is less prevalent in mathematics and science in relation to language arts and social studies (Becker, 2000; Gray et al., 2010; Means, 2008) which could be attributed to rigid beliefs about the nature of mathematics teaching and learning (Washira and Keengwe, 2011). Personal concerns, technological concerns, managerial concerns, perceptions of whether students were able to use the software, as well as the various roles teachers chose (all mentioned in Zbiek and Hollebrand's (2008) review of the literature on teachers' use of technology), ultimately decide students' learning experiences, which are influenced by teachers' beliefs and instructional practices (McCulloch et al., 2018). Teachers' confidence, knowledge and skills and the impact these have on the deployment of digital technologies - and therefore on their potential - in classrooms cannot be denied (Geraniou and Jankvist, 2019).

A further external barrier also includes the lack of research required to alter the beliefs and practices of teachers of mathematics, who could use technology to transform their practice but do not (Ertmer, 2005). Although standardised high-stakes testing has been frequently cited as the pressure which leads to a tendency to teach mathematics focussing on routine skill, which limits the possibilities of innovative uses of technology (Conole, 2008; Dede, 2010; Fullan and Langworthy, 2014; Star et al., 2014), it has been recognised that teachers will only expend the effort to change their current teaching practice if there is clear evidence this will lead to better learning outcomes (Means, 2010). Until the use of technology is seen to be of value in assessment (Donnelly et al., 2011) or more support is offered from both colleagues and management, teachers are unlikely to change (Fullan and Langworthy, 2014). Furthermore, the theory relating to the integration of both traditional instruction and inquiry-based approaches is lacking (Li and Ma, 2010; Maaß and Artigue, 2013; Noss et al., 2009). In the UK, widespread lack of government endorsement of technology in the mathematics classroom is a further barrier, with some organisations making recommendations to policymakers that there is no evidence digital technology improves examination performance (OECD, 2015; Parish, 2019).

2.1.6 Conclusion

The pace at which change is occurring in our world of digital technology indicates that there will be a need for further research, as it is struggling to keep up (Garrison and Kanuka, 2004; Graham, 2006, 2013). The poor channels of communication that educational policy makers have with researchers, teachers and any other people that experiment with the integration of technology at grassroots level, has been identified as an inhibitor to the progress of blended learning (Casanovas, 2011). This is particularly the case for blended learning within secondary education, where a large gap has been identified (Drysdale et al., 2012). This gap is now especially pronounced given the sudden transition to online learning in classrooms across the globe during the pandemic in 2020 and 2021.

Despite this gap, a growth in blended learning research within mathematics education is evident both in specialised journals and at international conferences (Borba et al., 2016). Although great diversity is seen in the empirical research relating to the use of technology, the learning experience has not been sufficiently transformed to unlock its perceived potential (Geiger et al., 2010; Hoyles, 2016; Reed et al., 2010; Selwyn, 2011), where the majority of teachers and students simply use technology to enhance traditional practice (Crompton, Burke and Gregory, 2017; Hyde and Jones, 2013; Oldknow, 2009) and research of more innovative, collaborative ways to use blended learning within mathematics education is limited (Borba et al., 2016).

Within the research field of blended learning in mathematics education, studies have examined instructional technology as academic support tools (Höffler and Leutner, 2007) and others examined differences between technology access and student outcomes (Harter and Harter, 2004) but there has been little research - if any at all - on the differences between viewers and non-viewers specifically of instructional videos (Hampton, 2014).

Very little research can be found on what the impact specific platforms of instructional videos, such as those of the Khan Academy, have on student outcomes (Kelly and Rutherford, 2017). Despite numerous marketing campaigns and anecdotal claims pertaining to the Khan Academy's positive impact on teaching and learning mathematics (e.g., Noer, 2012), the results of the limited literature on this remain inconclusive and inconsistent (Hampton, 2014). To highlight this further, Hegartymaths, which has become one of the most popular platforms for instructional videos in the UK during the last couple of years, has not been researched at the time of writing. Since the success of technology implementation has been linked to the software selected (Means, 2008), the type of tasks chosen (Sherman, Cayton and Chandler, 2017) and the decisions a teacher makes (Ertmer, 2005; Li and Ma, 2010; Drijvers et al., 2010; NCTM, 2015) I recommend these should be researched in the UK specifically, through the increasingly popular online platform, Hegartymaths. As this is the first doctoral research project centring on Hegartymaths, I hope that this thesis provides insights to others – both researchers and practitioners - and acts as springboard for further study into how to further unlock the potential of the platform.

Chapter 2: Literature Review Part 2

Mathematical knowledge and Hegartymaths

2.2.1 Introduction

This section of the Literature Review outlines what mathematical knowledge is and how it can be viewed from different philosophical stances, in addition to exploring how such knowledge is further characterised and defined in the field of mathematics education research. Further, I will draw together different pedagogical approaches to mathematics teaching to evaluate the possible pedagogical stances of, and teaching strategies that can be applied to the use of the Hegartymaths platform, as directed by my research questions:

1) *To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE?*
2) *Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?*
3) *How is Hegartymaths used in the most successful schools?*

How I decided to measure the impact of Hegartymaths on student outcomes at GCSE (my first research question) is addressed in the Methodology and Research Design chapters. As such, this literature review will focus in more depth on gaining insight from the literature into the following: which philosophical stance Hegartymaths is most aligned to; which type of mathematical knowledge Hegartymaths is best suited to, and which topics Hegartymaths is most successful in teaching students, in terms of pupil outcomes. Further, this sectioon will broach the various ways Hegartymaths can be used as a tool to bring about student success, as per my third research question.

The philosophical stances held by foundationalists and quasi-empiricists are important to consider in the pedagogical debate between behaviourism and socio-constructivism. The position one adopts informs the way mathematics is learned and taught within the classroom and school environment (Southwell, 1999), which is a key consideration as the way in which Hegartymaths is used by practitioners is very much bound to that individual teacher's philosophy; rarely is Hegartymaths prescribed as a standalone tool that is not aligned to what is happening in the classroom in some way.

Mathematics curriculum reform developed across several countries during the 1990s (Boesen et al., 2014; Niss at al., 2016). Traditionally, the curriculum tended to concern itself with what mathematical content should be the focus of study in terms of the concepts, notions, theories, methods and results (Boesen et al., 2014; Österholm, 2018). Although national mathematics curricula still set these to an extent, there is evidence of a shift that attempts to clarify the relationship between mathematical content and practice by introducing generic competencies such as conceptual understanding, problem solving, reasoning and communication skills, which can be seen in the mathematics curricula in several countries (Kilpatrick, Swafford, and Findell, 2001; Niss, 2003; Niss and Höjgaard-Jensen, 2002).

As such, this 'practical' use of mathematics is a major priority for both primary and secondary mathematics education today (OECD, 2009). Abstract knowledge as an end in itself has long been criticised due to calls to connect education with real life (Dewey, 1959a/1899) so as to make it relevant for students by providing opportunities to use their learning outside of the classroom context and test situations (Gainsburg, 2008; Grønmo, 2011; Pongsakdi, Laine, Veermans, Hannula-Sormunen, and Lehtinen, 2016). In this way, students learn mathematics based on their conceptual knowledge of the real world and are not taught to memorise formulas with the sole aim of passing a test (Boesen et al., 2014; Jonsson, Norqvist, Liljekvist, and Lithner, 2014).

Research into mathematical thinking has split mathematics knowledge into two distinct types: procedural knowledge and conceptual knowledge (Hiebert, 1986). Various different labels have been used to categorise these two modes of thinking needed to solve 'exercises' and 'problems' (Kantowski, 1977), more commonly known as 'routine' and 'non-routine' problems (Milgram, 2007), but others claim that there are three categories for mathematical processes: analytic, geometric and harmonic (which is both analytic and geometric together) (Krutetskii, 1976).

The trend in mathematics education research is similar, where procedural knowledge has tended to dominate in many areas (Stigler and Hiebert, 1999); procedural knowledge can be classified as knowledge of sequences of steps or actions that can be used to solve problems (Rittle-Johnson and Siegler, 1998). Over a decade ago, conceptual knowledge grew to become more of a focus within research into mathematical thinking (Star, 2005) which implies a leaning towards looking beyond how participants approach problem solving, to their broader grasp of mathematical concepts. Currently, within the realm of research on mathematical thinking within mathematics education, there is consensus that there are clear advantages to the acquisition of conceptual knowledge over procedural skill alone (Crooks and Alibali, 2014). A more detailed breakdown of conceptual knowledge follows in this literature review but, in brief, this mathematical knowledge type has been shown to equip learners with the ability to decide which process is appropriate according to the context of the mathematical problem (Byrnes and Wasik, 1991; Carr, Alexander, and Folds-Bennett, 1994; Garofalo and Lester, 1985; Greeno, 1978; Schneider and Stern, 2012). A further advantage has been identified as the way in which conceptual knowledge generates a greater degree of flexibility in problem solving, as learners who grasp the conceptual makeup of a mathematical procedure are more likely to be able to transfer and generalise that knowledge to a completely new problem (Baroody and Dowker, 2003; Baroody, Feil, and Johnson,2007; Blote, Klein, and Beishuizen, 2000; National Council of Teachers of Mathematics, 2000; Rittle-Johnson, Siegler, and Alibali, 2001). A further element of conceptual knowledge is the fact that it can also be used to check the reliability of a solution to a problem (Carr et al., 1994; Garofalo and Lester, 1985).

Today, the Department for Education categorises the questions they use to assess 16-year olds in the UK by broader mathematical topics as well as by three assessment objectives, where the subject aims and learning outcomes are defined as follows:

> "GCSE specifications in mathematics should enable students to:
> 1. develop fluent knowledge, skills and understanding of mathematical methods and concepts
> 2. acquire, select and apply mathematical techniques to solve problems
> 3. reason mathematically, make deductions and inferences and draw conclusions
> 4. comprehend, interpret and communicate mathematical information in a variety of forms appropriate to the information and context."
>
> (DfE, 2013, pg. 3)

This section of the literature review will explore why mathematics is categorised in these various ways and, further, highlight the nuances of these given categories. I intend to convey what the literature believes are effective teaching strategies for the different categories in order to identify which are best suited to learning online through Hegartymaths.

2.2.2 What is mathematics? A philosophical stance

In this section of the Literature Review, I will look at the broad philosophical views of what mathematics is, and how this affects how teachers believe it is best taught. Hegartymaths is a tool that works alongside classroom teaching and this part of the Literature Review is most concerned with my third research question in particular: *How is Hegartymaths used in the most successful schools?* Part of this discussion is not just the way in which Hegartymaths is used but also the beliefs a teacher has that underpin their choices in implementing it. Although my survey questions do not explicitly explore these beliefs, it is important to recognise that Hegartymaths can be used in different ways and ultimately the success of this could affect the philosophy of mathematics that a teacher or department subscribes to.

The Platonist tradition suggests that mathematics is an entity waiting to be discovered and if this school of thought is adopted it is considered sufficient to present the curriculum as knowledge of facts, definitions and algorithms. Euclid (365-275 B.C.) first explained mathematical reasoning through a consistent network of postulates, corollaries, axioms and theorems. For millennia, attempts were made to vindicate mathematics as a discipline free from error and from descriptions such as the "mother" (Mura, 1995, p. 390), the "queen of all sciences" (McGinnis, Shama, McDuffie, Huntley, King, & Watanabe, 1996, p.17) and the "most perfect of all sciences" (Lakatos, 1986, p. 31), but it was mainly Lobachevsky (1793-1856) who brought Euclid's infallibility to question by deducing Euclid's fifth postulate from other axioms (Baldor, 1984).

The foundationalist movement, which also includes symbolism and intuitionism, was criticised in securing mathematics as an abstract, absolutist, universal and infallible system. However, Hersh (1979) and Rogerson (1994) justify how the formalist and logicist paradigms have largely influenced the way students and teachers have learnt what mathematics is, and behaviourist perspectives derived from the foundationalist legacy influenced school mathematics and models of teacher education in the world (Laurenson, 1995; Moreira & Noss, 1995; Robitaille & Dirks, 1982; Thom, 1986). Learning mathematics, when viewed from this perspective, concerns itself with teaching as an almost separate and distinct entity.

Teaching mathematics by 'telling' was commonplace in the past. 'Telling' refers directly to the central teaching action of demonstrating the proper sequence of steps in mathematical procedures (Stodolsky, 1985; Putnam, 1992). Stating facts and demonstrating procedures to students were the key components of mathematics teaching, and by drawing on their own experiences as students, teachers believed that this was necessary for learning. Ashton (1985) defines a teacher's sense of efficacy as their belief in their own capacity to effect student learning in a positive way. The process of imparting mathematics allows teachers to develop efficacy firstly by outlining manageable mathematical content that they themselves have studied extensively and secondly, providing clear expectations and instructions for what they must do with that content to affect student learning (Smith, 1996). The content itself is a set of facts and procedures that lead to determinant 'answers', which are found at the back of a textbook that contains every possible problem students are expected to solve. The teacher who interpreted the textbook was seen as an intermediate authority for students on matters of mathematical truth.

Behaviourism was the prevalent theory of learning from the 1950s through to the 1970s, which suggests learning can be controlled by affecting the variables of the situation, the behaviour, and the consequences of behaviour (Bell, 1978). It explains learning through the observable interactions of the learner with the environment without concluding what is happening inside the mind of the learner. The theory based on the stimulus-response model of Skinner (1953) gave rise to 'rote' or 'programmed' learning.

The 'quasi-empirical' movement proposed that mathematics should be excluded from the category of hard sciences as it is not a 'discovery', as Plato once suggested. It sees mathematics as a human creation born of and nurtured by practical experience that should be open to revision and challenge so it can continually grow and change. The transition to the quasi-empirical approach saw a renewed interest in the application of mathematics that was previously restricted due to foundationalist abstract constructs (Robitaille and Dirks, 1982; Rogerson; 1989). Learning today is more frequently seen as an adaptive and experiential process rather than a knowledge transference activity (Candy, 1991). New situations encountered by learners allow them to look for similarities and differences against their own cognitive schemata. These are the end-products of conflictive knowledge waiting to be resolved through reorganising schemes of knowledge (Phillip, 1995). Pupils can determine their knowledge using their own way of processing information and according to their own beliefs towards learning (Biggs and Moore, 1993). Constructivism allows a place for previously mentioned reflective oriented learning activities such as investigations, problem solving, group learning and class discussions (Murphy, 1997; Wood, Cobb and Yackel, 1991).

The very foundations of behaviourism were criticised by Skemp (1976) who purported that teaching students to move from A to B, B to C and then from C to D, did not guarantee that they acquired a holistic understanding of how A, B, C and D are related, if A, B, C and D are four steps that appear in a learning hierarchy. Moreover, if they did not achieve a holistic understanding, pupils were unable to return from D to A. Erlwanger (1975) revealed that children who had succeeded in acquiring mastery level lacked any real understanding of what they were doing. As a result of their lack of links between the skills, they could not apply the mathematics they 'mastered' and they had developed an inadequate, mechanical view of the nature of mathematics. Freudenthal (1979) also dented the findings of Bloom and Block by questioning the validity of their research, claiming that they had applied dubious statistical techniques.

Efforts to establish an enquiry-mathematics tradition refer to 'intellectual autonomy', which is characterised as students' awareness and willingness to draw on their own intellectual abilities when coming to mathematical judgements and making strategic decisions (Cobb and Yackel, 1998). Further, it has been argued that judicious 'telling' in situations such as when providing useful terminology and counterexamples to student conjectures do support students' reasoning, but that the teacher must be aware of when to mediate between accepted methods and mathematical knowledge, and the individual classroom's intellect (Ball and Chazan, 1994). Selective telling is very different from the model described earlier where the teacher is the sole provider of knowledge (Heaton, 1994).

The most significant shift in learning mathematics in school today is influenced by constructivism, both along the lines of Piagetian constructivism and of Vygotskian sociocultural theory. Both perspectives are useful at different times to make sense of learning and teaching situations. The first is related to the individual attempting to make sense of both the physical and social world around them, creating mental schemata through the process of assimilation and accommodation, which influences many of the techniques already discussed. The second recognises that internalisation occurs through language use and sees the individual as part of society or social groupings, which has been largely influential in arranging pupils in groups for learning and classroom discussions that were almost non-existent in the past.

Defining mathematics education is a complex task as it draws from a number of disciplines and research (Silver and Kilpatrick, 1994), which makes the task of placing Hegartymaths within one specific philosophical standpoint even harder. The philosophies discussed above that assert the objectivity of mathematics as a prized possession, typically named positivist, do not fit well with the philosophical bases of mainstream contemporary education: hermeneutics, analytic philosophy and postmodernism, where truth is processed through language and resultantly knowledge is brought about through discursive systems (Brown and Walshaw, 2012). As such, the purpose of contemporary mathematics education research should not be to pursue a perfect solution; instead it should prioritise generating analytical filters that, in line with postmodern theory, are likened to tools that disrupt systems of power (Foucault, 1975/1996).

As the link between theoretical perspectives and methodologies is undeniable (LeCompte, Preissle, and Tesch, 1993), it follows that many mathematics education researchers turned to interpretivism and constructivism. The aim was now to understand social phenomena rather than to predict it (Steffe and Tzur, 1994) and teacher-student, student-student interactions as well as the relationship they have with mathematics, were examined to inform teaching and learning, often illustrated by the Instructional Triangle (National Research Council, 2001). The complexities seen within these interactions (Stinson, 2006) led to the social turn, which resulted in theoretical perspectives that posit reasoning and thought as products of social activity (Lerman, 2000).

2.2.3 The difference between procedural and conceptual mathematical knowledge

Within the research field of mathematics education, enquiry into the classification of mathematical knowledge (Österman and Bråting, 2019) has brought about the split between procedural and conceptual knowledge, which has ultimately provided a platform for empirical studies in addition to the development of theoretical frameworks (Kieran, 2013). It is important to note that conceptual and procedural knowledge cannot always be viewed separately but nonetheless it is useful to identify the differences between the two knowledge types so as to further our understanding of knowledge development (Österman and Bråting, 2019). It follows that I will now look at the differences in the nature of these two types of knowledge so as to adopt definitions of each. This will enable me to interrogate whether the Hegartymaths platform might transmit knowledge with different degrees of success, depending on the knowledge type.

Turning to the nuances of procedural and conceptual knowledge respectively, the former can firstly be characterised as a knowledge type comprised of procedures used in solving mathematical problems, where the procedures are presented as prescribed ways of manipulating symbols (Hiebert and Lefevre, 1986). Procedural knowledge can also be defined as ‘instrumental understanding’, which refers to the ways in which students learn a suite of fixed and specific plans in order to solve a specific kind of task (Skemp, 1978). Put another way, procedural knowledge can be seen as ‘knowing how’: a process that refers to the acquisition of the knowledge of the steps and stages needed to reach various goals. Such procedures have been further categorised into constructs like skills, strategies, productions, and interiorized actions (Byrnes and Wasik, 1991; Rittle-Johnson et al., 2001; Canobi, 2009). More specifically, procedures can be either algorithms (a predetermined series of actions that, when followed and performed accurately, will result in the correct answer) or secondly, as possible actions that must be sequenced appropriately to solve a given problem (such as the stages involved in solving linear equations, for example the first step could either be to 'collect like terms' or 'expand the brackets', which depends upon whether the question involves brackets on both sides of the equation, if any at all). This type of knowledge is honed through practising problem-solving and therefore is unavoidably tethered to particular examples of problems; the sequential nature of procedures keeps them distinct from other knowledge types (Hiebert and LeFevre, 1986).

Limitations emerge when working towards a definition of procedural knowledge, as the term itself suggests firstly what is known – that being knowledge of procedures – and secondly, that procedures – such as algorithms - can be known in a 'surface', superficial way, without making deep, integrated connections within a network of knowledge (Star, 2005). A further constraint in defining procedural knowledge is oversimplification through the reductive comparison of rote, memorised knowledge with computational skill or procedural knowledge (Baroody, 2003; Baroody et al., 2007). Although procedural knowledge - and the way it is acquired - can be viewed as more than empty facts taught by rote, when this type of 'surface' knowledge is internalised by the learner, it is classified as procedural and this is a central part of the definition I am working towards for the purposes of this research project. Typically however, procedural knowledge is defined by researchers in terms of its sequential nature and the way in which it prescribes distinct stages for the completion of problems (Hiebert and Lefevre, 1986). Over time, labelling procedural knowledge has occasionally resulted in somewhat narrow and limiting definitions, as I have mentioned already, although there is appetite within the field of mathematical education research to ensure that this does not become the case (Rittle-Johnson and Schneider, 2015). The complexities of defining procedural knowledge have been further compounded by psychology research into computational models, where procedural knowledge can be equated to implicit knowledge that cannot be verbalised or, put another way, knowledge that can only be detected through performance and which cannot be reported (Anderson, 1993). Over time, pinning down definitions of explicit and implicit knowledge has been a contentious process but it has been accepted and surmised that procedural knowledge, although deemed inaccessible in many senses, is integral to virtually all computational models that have procedural skills entrenched within them (Sun, Merrill, and Peterson, 2001) because such models are often comprised of procedural knowledge that has become automatic – or 'automatized' - as a result of constant practice over time (Rittle-Johnson and Schneider, 2015). This is a key feature of cognitive load theory, which will be discussed further in this literature review. It should be acknowledged, however, that in mathematical problem solving, procedures are harnessed by the student that are not 'automatized', but instead need to be selected carefully, reflected upon and then sequenced; as such, this type of procedural knowledge arguably can be verbalised (Star and Newton, 2009).

Turning to widely accepted definitions of conceptual knowledge, it has often been characterised as a knowledge type that is founded on an inter-connected web of knowledge, where the way in which the knowledge is linked has the same status as the information itself (Österman and Bråting, 2019). Critically, this entire knowledge type relies on relationships (Hiebert and Lefevre, 1986). This model is further reinforced by definitions of relational understanding (Skemp, 1976). While there are differences within the lexicon used to characterise conceptual knowledge, ranging from terms such as 'connected web' and 'networks' to 'conceptual structures' (Österman and Bråting, 2019), all the definitions point to a set of circumstances in which a student calls upon specific mathematical concepts while simultaneously drawing on their understanding of an overarching system of concepts (Hiebert and Lefevre, 1986). Knowledge of concepts is most frequently referred to as conceptual knowledge (Byrnes and Wasik, 1991; Rittle-Johnson, Siegler, and Alibali, 2001; Canobi, 2009) and this is a type of knowledge that is not directly linked to specific problems because, by their very nature, a concept is an abstract, generic notion that is either implicit or explicit, and furthermore does not necessarily have to be able to be verbalised (Goldin Meadow, Alibali, and Church, 1993). Broadly then, conceptual knowledge can be viewed as comprehension of mathematical operations, concepts and relations (Kilpatrick, Swafford, and Findell, 2001). It should be noted that conceptual knowledge can also go by the name of conceptual understanding or principled knowledge. There are further, more nuanced definitions of conceptual knowledge which embody not only knowledge of concepts but also define this knowledge type as one way that concepts can be known, such as in an interconnected way. One such nuanced definition proposed that conceptual knowledge is knowledge about facts and principles without the requirement that the knowledge be richly connected (Rittle-Johnson and Schneider, 2015). This definition is lent support by further research into conceptual change that led to a twofold conclusion: firstly, the disjointed and fragmentary nature of learners' conceptual knowledge and the need for it to be integrated throughout the learning process and secondly, that the experts' conceptual knowledge is continually expanding, becoming increasingly better organised as a result (diSessa, Gillespie, and Esterly, 2004; Baroody, Feil, and Johnson, 2007; Schneider and Stern, 2009).

There is a wide consensus that conceptual knowledge has a significant role in mathematics learning (Crooks and Alibali, 2014). The literature points to several different ways that conceptual knowledge might prove useful, in addition to how it interrelates with procedural knowledge. First, it is implied that the teaching of conceptual knowledge alongside procedures bestows the learner with more general benefits, such as the acquisition of a more robust and better-entrenched understanding of mathematics, that also has greater longevity (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010). If this is the case, it will be necessary for the teaching of conceptual knowledge to be led by the teacher in the classroom setting as Hegartymaths, although a platform that does demonstrate the links between mathematical topics, is also designed in such a way that learners are able to work on certain problems in isolation, as far as possible. It has also been argued that conceptual knowledge generates flexibility when problem solving, as those who grasp the underlying conceptual aspects of the problem have an increased likelihood of being able to generalise and subsequently transfer this knowledge to novel scenarios (Blote, Klein, and Beishuizen, 2000; National Council of Teachers of Mathematics, 2000; Rittle-Johnson, Siegler, and Alibali, 2001; Baroody and Dowker, 2003; Baroody, Feil, and Johnson, 2007;), as opposed to replicating the same procedure through the completion of similar exercises. Again, Hegartymaths is not particularly well-suited to giving students the opportunity to apply their knowledge to unfamiliar scenarios; in fact, the questions in the quiz element mimic the format modelled in the video tutorials and do not present the learner with opportunities to apply their understanding to completely novel problems. Further, studies into conceptual knowledge have revealed its use in enabling people to judge which type of procedure is applicable when a problem is presented (Brownell, 1945; Greeno, 1978; Garofalo and Lester, 1985; Byrnes and Wasik, 1991; Carr, Alexander, and Folds-Bennett, 1994; Schneider and Stern, 2012) as well as a means of verifying whether a solution to a given problem is a reasonable one (Brownell, 1945; Garofalo and Lester, 1985; Carr, Alexander, and Folds-Bennett, 1994).

Despite the shift in both research and educational practice towards foregrounding conceptual knowledge, there remains a number of hurdles that serve as obstacles to reaching a shared understanding of what precisely conceptual knowledge is and furthermore, how best to measure it (Crooks and Alibali, 2014). Because conceptual knowledge encompasses such a broad and diverse spectrum of constructs that have been both defined and measured in an assortment of ways, it has become increasingly complex to navigate exactly how conceptual and procedural knowledge interrelate and how to use these findings to inform teaching instruction in educational practice (Baroody et al., 2007; Star, 2005).

For the purposes of my research, it is necessary to summarise the distinctions between the two knowledge types to reach definitions of each that I intend to refer to in subsequent chapters:

Knowledge Type	Depth of Understanding	Connectedness of Knowledge	Application of Knowledge	Awareness of Methods	Common Teaching Approaches
Procedural	Surface	Isolated	Inflexible	Recalling the steps	Drill and practice
Conceptual	Deeper	Interlinked	Flexible	Explaining the steps	Questions and discussion

Table 2.2.1: Comparison of procedural and conceptual knowledge

Whilst I recognise the reductive nature of the grid above, as well as the arguments made within the literature that concern the inseparability of the two knowledge types, it is useful to delineate each type in isolation and position them as opposites. This will enable me to pinpoint the strengths and weaknesses of the mathematical content that is taught through Hegartymaths. I will define procedural knowledge as that which views mathematics as a tool to reach a solution to a given, isolated and recognisable problem through a series of inflexible steps that must be known at a surface level, and can be acquired through drill and practice. In contrast, I will define conceptual knowledge as a deeper form of understanding of mathematics, which is acquired through an interactive, enquiry-based context where patterns observed can then be explained and applied across various mathematical scenarios.

Having defined procedural and conceptual knowledge as opposites, this literature review will now turn to explore how these types of knowledge manifest themselves within mathematical reasoning and both routine and non-routine problem solving.

2.2.4 Mathematical reasoning

It has been argued that rote learning, defined as a learning process whereby something is repeated until it has been internalised and memorised, can result in difficulties in learning and attainment (Lithner, 2004, 2008). However, it has also been argued that the act of memorising stem sentences by rote frees pupils' working memory to such an extent that they are then able to articulate 'their ideas with mathematical precision and clarity' (NCETM, 2015). A theoretical framework for mathematical reasoning aims to differentiate between two different versions of the reasoning process, called imitative and creative reasoning (Österman and Bråting, 2019). Imitative reasoning is connected to rote learning and refers to the way in which learners are taught to be able to recall an answer to a specific task in full, but without necessarily knowing the ways in which the sequential actions interrelate and build on one another. Imitative reasoning can also be characterised as a strategy whereby a solution to an algorithm is recollected, similar to the widely-accepted understanding of procedural knowledge and instrumental understanding as processes whereupon chains of prescriptions, or fixed and specific plans, are learned (Skemp, 1976; Hiebert and Lefevre, 1986), which is in line with the constructivist approach to the acquisition of knowledge.

Creative reasoning, then, is believed to occur when a learner, confronted with a problem, forms a strategic sequence of reasoning that is novel to them. The learner is able to support this newly-formed reasoning sequence with justifications for their choice of strategy that are rooted in a deep understanding of the mathematical properties of the components of the problem, in addition to having secure relational understanding of how discrete pieces of information are linked to one another within a wider network of knowledge and the ways each stage of the problem solving process are related to the final outcome (Skemp, 1976; Hiebert and Lefevre, 1986). The connection to definitions of conceptual knowledge is clearly evident here.

These two types of reasoning can therefore be summarised as follows: imitative reasoning is a process whereby the solution to a problem is accessed by following a known pathway, or is immediately recognised through recollection whereas creative reasoning is a process where the solution is created by the learner (Lithner, 2008). Put another way, these definitions aim to represent the difference between having a surface understanding of knowledge that might have been rote-learned, for example, and having an intrinsic grasp of the mathematical properties of a given operation that leads the learner to be able to apply this knowledge to a broad range of situations and contexts, in addition to understanding the ways that the discrete knowledge is interconnected. The implications for teaching practice are manifold; researchers are focused on developing ways to enable teachers to enhance their pupils' conceptual knowledge as opposed to limiting it to procedural knowledge, which is deemed insubstantial (Hiebert and Lefevre, 1986; Jonsson et al., 2014). Hegartymaths, where teacher-pupil and pupil-pupil interactions do not exist, is resultantly more suited to the teaching of procedural knowledge. It can therefore be seen to be in direct opposition to the mandate of equipping teachers to focus on conceptual knowledge, if viewing the platform as another tool for drill and practice. However, this view is a fairly limiting one as Hegartymaths can be seen as a tool that takes the necessary 'rote' part of mathematics out of the classroom, thereby creating more time in class to delve deeper into understanding mathematical concepts.

It is important to note that there are arguments within the field of research that maintain that there are benefits to procedural knowledge, instrumental understanding and imitative reasoning and there have been calls for procedural knowledge to be foregrounded within mathematics education research, which has come about as a result of the acknowledgement that the development of novice learners' procedural knowledge has not been looked into in sufficient depth (Österman and Bråting, 2019). A further potential explanation is that theoretical understandings of procedural knowledge are associated with limiting assumptions about what is known about procedures. However, reconfiguring and redefining procedural knowledge to challenge or subvert such assumptions would have considerable implications for the field of research as well as on educational practitioners themselves (Star, 2005). From a mathematics department's perspective in school, one of the most common areas of constant development is revisiting what the teachers within a department should teach consistently across all of their classes, and how these procedures should be taught. For example, having a consistent procedure used to multiply numbers for all pupils in all years is clearly a powerful one, especially as pupils experience different teachers during their secondary education. It follows that it would disadvantage pupils to have to learn different methods for this skill every time they changed teacher, especially as multiplication is an example of a procedure that is rarely fully understood by the pupils, but always required. Once the decision has been made by the department to fix a method, the next stage is to decide on a common approach. In certain scenarios, where the department cannot decide on the procedure or do not have the experience or expertise to teach a chosen method, Hegartymaths could aid teachers in both the delivery and explanation of the procedure and provide another level of consistency, provided the chosen method is the same as Hegartymaths' one.

It has also been alleged that establishing difference between conceptual and procedural knowledge is a false dichotomy as it is an oversimplification to extricate the two types of knowledge from one another and to view them as individual parts of the process of learning mathematics (Kieran, 2013). Integral to this criticism is the notion that it is fallacious – and even damaging - to view one type of knowledge as superior to the other. This viewpoint has arisen as a result of the claim that procedures are in fact conceptual in their composition and contain significant conceptual components (Kieran, 2013). The detrimental impact of this false dichotomy has been argued to be most pronounced in the research into and teaching of algebra, wherein the knowledge required to solve functions is deemed to be solely procedural manipulation of symbols and where conceptual knowledge plays little or no role (Österman and Bråting, 2019). Algebraic examples have since shown the simultaneous demand for both procedural and conceptual knowledge to be harnessed while being solved (Kieran, 2013).

Returning to the difference between imitative and creative reasoning, it is important to outline why these might be viewed as opposite modes (Bergqvist and Lithner, 2012). The way in which the role of algorithms in mathematics education is viewed can helpfully illustrate the development from executing numerical, computational and mechanical skills – which are considered imitative - to providing verbalised explanations and justifications for the processes behind the operations involved, which is one way to characterise creative reasoning (Österman and Bråting, 2019). Algorithms are typically viewed as operations that do not build a learner's understanding or enhance meaning in any way, but that do have an advantage in that they enable students to reach the correct conclusion efficiently (Brousseau, 1997; Hiebert, 2003). Creating original solutions to mathematical tasks is often seen as a more desirable trait to instil in a student learning the subject, whereas the blanket, mechanical application of rules and algorithms is seen as far less impactful in terms of developing the learner's holistic understanding of mathematics (Österman and Bråting, 2019).

At GCSE level in the UK, pupils are tested using the following objectives, set by the Department for Education in November, 2013:

Assessment Objectives		weighting	
		F	H
AO1	**Use and apply standard techniques**	50%	40%
	Students should be able to:		
	accurately recall facts, terminology and definitions		
	use and interpret notation correctly		
	accurately carry out routine procedures or set tasks requiring multi-step solutions		
AO2	**Reason, interpret and communicate mathematically**	25%	30%
	Students should be able to:		
	make deductions, inferences and draw conclusions from mathematical information		
	construct chains of reasoning to achieve a given result		
	interpret and communicate information accurately		
	present arguments and proofs		

	assess the validity of an argument and critically evaluate a given way of presenting information		
	Where problems require candidates to 'use and apply standard techniques' or to independently 'solve problems' a proportion of those marks should be attributed to the corresponding Assessment objective.		
AO3	**Solve problems within mathematics and in other contexts.**	25%	30%
	Students should be able to:		
	translate problems in mathematical or non-mathematical contexts into a process or a series of mathematical processes		
	make and use connections between different parts of mathematics		
	interpret results in the context of the given problem		
	evaluate methods used and results obtained		
	evaluate solutions to identify how they may have been affected by assumptions made		
	Where problems require candidates to 'use and apply standard techniques' or to 'reason, interpret and communicate mathematically' a proportion of those marks should be attributed to the corresponding assessment objective.		

Table 2.2.2: Description and weightings of GCSE mathematics assessment objectives set by the Department of Education

AO1 questions are assessing what I have defined as pupils' procedural knowledge, whereas AO2 and AO3 questions appear to be more interested in testing pupils' conceptual knowledge. It is interesting to note that the recommended weightings for the assessment objectives that the Department of Education has set for exam boards to use when creating the exams give the impression that the UK values both procedural and conceptual knowledge in equal measure in the foundation paper, and this is almost the case in the higher papers too. Even more noteworthy is that when an independent assessment of the breakdown of the marks awarded in the June 2019 papers for examination boards Edexcel and AQA was conducted (by Pinpoint Learning), the design of the questions seemed to overwhelmingly favour AO1 questions and hence were seen to prioritise procedural knowledge:

AQA Foundation GCSE papers		
Assessment Objective	Total marks available	% of total marks
AO1	164	68%
AO2	72	30%
AO3	4	2%

AQA Higher GCSE papers		
Assessment Objective	Total marks available	% of total marks
AO1	137	57%
AO2	93	39%
AO3	10	4%

Table 2.2.3: Perceived assessment objective weightings assigned by Pinpoint Learning for the Summer 2019 AQA GCSE in mathematics

Edexcel Foundation GCSE papers		
Assessment Objective	Total marks available	% of total marks
AO1	188	78%
AO2	26	11%
AO3	26	11%

Edexcel Higher GCSE papers		
Assessment Objective	Total marks available	% of total marks
AO1	171	71%
AO2	34	14%
AO3	35	15%

Table 2.2.4: Perceived assessment objective weightings assigned by Pinpoint Learning for the Summer 2019 Edexcel GCSE in mathematics

A further analysis of the average scores as a percentage of the total marks available in the different assessment objectives does indicate that the AO1 questions were overwhelmingly better-answered by students across both tiers and boards:

AQA Foundation GCSE papers			
Assessment Objective	Total marks available	Average marks gained	% of total marks gained
AO1	164	77.18	47%
AO2	72	22.59	31%
AO3	4	0.72	18%

Edexcel Foundation GCSE papers			
Assessment Objective	Total marks available	Average marks gained	% of total marks gained
AO1	188	107.98	57%
AO2	26	8.94	34%
AO3	26	8.4	32%

AQA Higher GCSE papers			
Assessment Objective	Total marks available	Average marks gained	% of total marks gained
AO1	137	74.87	55%
AO2	93	42.92	46%
AO3	10	3.05	31%

Edexcel Higher GCSE papers			
Assessment Objective	Total marks available	Average marks gained	% of total marks gained
AO1	171	102.69	60%
AO2	34	14.87	44%
AO3	35	8.19	23%

Table 2.2.5: Marks gained according to exam board, tier and assessment objective

Hegartymaths, when viewed solely as a standalone tool in place of the traditional classroom setting, is far more aligned to the procedural knowledge the AO1 questions test for, as opposed to the teaching of how to solve AO2 and AO3 questions. When considering the vast amount of marks available to students in the AO1 category, Hegartymaths has positioned itself wisely in order to maximise their users' GCSE performance. A teacher who uses Hegartymaths, and who is aware of the difficulty AO2 and AO3 questions pose to students, can maximise the online platform to teach some of the less difficult AO1 procedures to then free up time to devote to teaching the conceptual knowledge required to solve AO2 and AO3 questions. This could be viewed as a risky strategy as there are fewer marks available for these types of questions, but with careful in-class testing of the knowledge students acquire through Hegartymaths at home, it seems there is scope for this to be a risk-free and efficient way of teaching, where the rewards can be great.

2.2.5 Routine vs non-routine problem solving

It follows that there are recommendations from the field of research to educators that encourage them to set non-routine, challenging and engaging mathematical problems for their learners (Schoenfeld, 1985). This has come about as a result of the challenges students encounter when confronted with novel problems that require the application of domain processes and knowledge (Lee and Chen, 2008). Students often struggle with novel mathematical scenarios because the bulk of their practice of problem solving has centred on following step-by-step worked examples (Polya, 1957) and on rote learning and copying standard solution approaches, issued to them by their teachers or found in textbooks (Harskamp and Suhre, 2007). By flooding pupils with routine problems while in the novice stage of their learning, they become accustomed to the process of simply substituting new data into a formally-solved general problem framework (Polya, 1957) without being equipped with the knowhow to solve completely new and decontextualised problems. That is not to say that students who struggle with these types of problems suffer from a paucity of mathematical knowledge or aptitude but that they are deploying that knowledge and those skills unproductively and ineffectively (Garofalo and Lester, 1985; Schoenfeld, 1987; Van Streum, 2000).

A further dimension to the endorsement of non-routine problem-solving is considered to be the way in which these types of tasks effectively engage students' intellects and heighten their mathematical curiosity, as well as honing their reasoning capabilities (Lee and Chen, 2008). Non-routine problems can also allow for contrasting strategies to be employed by those solving them (English and Halford, 1995; NCTM, 1991; Stein, Grover, and Henningsen, 1996); the fact that there are manifold ways to solve the problem usually means that there is scope for the learner to have to work out how to solve the problem, as opposed to immediately recognising the procedure required.

2.2.6 The role of interactive software in teaching problem solving

It has been suggested that students are taught to internalise ways to self-regulate their learning when it comes to problem solving, so that they can approach non-routine problems without failure (Schoenfeld, 1992). It follows that computer software and online platforms, that have an interactive approach (insofar as they are adaptive to the user's capacities, although these are limited in comparison to a classroom-based teacher-student dynamic), may play an instrumental role in supporting instruction in problem solving. Interactivity denotes a process whereby the user is given feedback (that is often individualised) and prompts designed to assist the learner in finding their way to a solution; crucially, the user is in control of the process (Lee and Chen, 2008). One such example of an interactive problem-solving computer programme for American high school mathematics provided students with a series of problems from which to choose, and prompted them throughout the different phases of the process (Harskamp and Suhre, 2007). As a result, the pupils who were exposed to the software were reported to have developed increased proficiency in their capacity to problem-solve when compared to peers who received traditional instruction; it is thought that the use of prompts might be the active reason for the success of these learners (Harskamp and Suhre, 2007). Further, an online multimedia whiteboard system was developed to support younger students with their problem-solving abilities which not only reported that the users were satisfied and interested, but further demonstrated that the software was especially helpful as a means of facilitating collaborative learning (Hwang, Chen, and Hsu, 2006). Other software platforms have been deployed – such as MathCAL - which is designed around Polya's stages of problem-solving – which has reportedly been successful in tackling underperformance in students who have a lower ability to solve problems (Hwang, Chen, and Hsu, 2006). The evaluation of the MathCAL study also pointed to the effectiveness of the assistive prompts in improving the learners' skills at each step of the problem-solving process. Blending maths learning with technology could therefore have a twofold impact on the learners, in terms of developing their problem-solving capacities as well as improving their attitude towards the discipline. While the studies referenced above suggest the positive impact of using technology, it is important to note that these computer programmes and online platforms did not expose the learners to non-routine problems.

Hegartymaths, whilst being an online platform, does not offer this level of feedback, although it does allow the teacher to interact by giving prompts, albeit not necessarily during the time a student is solving the problems. Furthermore, students are solely exposed to routine problems in the quiz section, which have been modelled prior to this during the video tutorial.

2.2.7 The role teaching strategies play when teaching mathematics

It is important to consider the processes by which students learn mathematics, and the implications of these findings for educational practice. A number of distinct pedagogical approaches that are commonly applied to the teaching of mathematics will be covered in the section following this one, as well as some common strategies that are found in all the overarching approaches. In this section I will examine why it is important to consider teaching strategies in general before recognising barriers that might hinder the extent to which Hegartymaths can be aligned to these teaching strategies.

The teaching triad of: the mathematics itself, the teacher and the learner (Steinbring, 2011) is a dynamic wherein the teacher is positioned as a go-between, facilitating the learner's ability to understand the mathematics, and also to develop the learner's intuitive understanding of mathematical scenarios (Nunes et al., 2009). This process of linking the learner with the mathematics, mediated by the teacher, is achieved through the teacher's pedagogical skill and resources as they guide their learners to a position where they are able to internalise both concrete material and representations to then apply to novel situations (Streefland, 1991; Carbonneau et al., 2013). Teachers employ a range of strategies to enable their students to make links between the actions they execute using the materials they have been given, and to develop related mathematical representations themselves (Nunes et al., 2009). By using models of problems, mathematics educators can support their learners as they use the models to guide them to approach related problems, especially when the students' intuition is not sufficient (Streefland, 1991). How to approach these types of models does need to be directly and explicitly addressed by the teacher; the students should not be left to explore and decipher the models completely on their own (Kirschner et al., 2006). Although Colin Hegarty, the teacher of the video tutorials, does guide pupils through the models he exposes pupils to, without teacher supervision it is arguably hard to guarantee that students are not left to their own devices to decipher models and create their own connections through the videos, which can then become entrenched as misconceptions. The advocates of direct and explicit instruction would also be against this 'flipped learning' model, even if the modelling on the pre-recorded video were of a better standard to that delivered by an educator in the 'direct instruction' classroom, unless of course you could guarantee purposeful engagement. When students struggle with the pre-recorded material, there is no opportunity for the teacher to use further representations or explain models differently according to individual needs. However, when students arrive to class confused after having watched an online tutorial that they have struggled to understand, and are armed with questions for the teacher, there is an argument that they will be more likely to be engaged to learn to rectify what they have misunderstood. Further, there is no guarantee that they would not have also been confused if it was learnt initially in a classroom.

The various ways that researchers and practitioners develop learners' mathematic aptitude and competence has been defined as a process whereby the teacher facilitates the learner's capacity to build on, transform and reorganise their existing mathematics knowledge (Donovan and Bransford, 2005). This process is especially crucial in the instances where the student might have pre-existing knowledge that could disrupt the new learning (Brown et al., 2018). Hegartymaths has been created in a way that encourages pupils to recognise and remedy any prerequisite prior knowledge that is needed before they are exposed to new learning. The section labelled 'building blocks', which is found under every video tutorial, lists all the pre-requisite video tutorials together with a question that students should be able to answer before attempting to learn the new material. The extent to which pupils actively engage with this, however, greatly depends on the degree to which the teacher makes reference to this and, further, on how convincing the teacher's explanation is for why it is crucial students ensure they attempt the learning in the correct order.

It has come to be understood that mathematics competence requires a degree of metacognition (Donovan and Bransford, 2005) although metacognition when applied to mathematics education should be considered as separate to generic definitions of the concept (Brown et al., 2018). Metacognition itself has a range of definitions given to it by researchers: "thinking about thinking" (Adey and Shayer, 1994); "learning to learn" (Higgins et al., 2005); the process whereby the learner is able to continually make sense of what they are learning through reflecting and explaining (Mason, 1999; Donovan and Bransford, 2005); the way in which a learner can reason and justify in order to prove a mathematical solution (Mason, 1999;

Kilpatrick, Swafford and Findell, 2001). Mathematical metacognition encompasses both generic elements – deduction or logic, for example – and also explicitly mathematic components. It has been argued that explicitly teaching pupils how to engage in mathematical dialogue can be beneficial to their development of metacognitive strategies (Donovan and Bransford, 2005; Kyriacou and Issitt, 2008), though the pedagogical skill required in establishing fruitful and meaningful mathematical talk in classrooms is significant (Stein et al., 2008). Hegartymaths, as a standalone platform, does not integrate any opportunity for pupils to learn from each other through discussion. The teacher can however build more time for productive peer discussion to take place both in or out of class, with the aid of the video tutorials.

The success of pedagogical approaches in mathematics education is likely to vary according to the specific mathematical knowledge required for a given problem. It will also vary according to the differences in the nature of the learner. For example, it has been suggested that direct instruction has a place in the teaching of certain mathematical operations at specific stages of student development (Gersten, Woodward, and Darch, 1986), while the improvement of learners' reasoning skills or the ways misconceptions are tackled would better rely on an alternative strategy to explicit instruction. Several current modes of thought centre on how cognitive science can influence practice in mathematics education, most notably the insights into the constraints of the working memory versus the limitless schemas of the long term memory (Alcock et al., 2016; Gilmore et al.; Wiliam, 2017) (Paas, Renkl, and Sweller, 2003). These findings have had profound implications for teachers in terms of their instructional technique as sophisticated schema can be summoned into the working memory from the long term memory, yet they are processed as just one element and thus the learner's cognitive load is reduced. Reducing cognitive load has become central to contemporary educational discourse; the generation effect points to the way in which learners have an increased ability to remember ideas that they have, even in part, generated themselves (Chen, Kalyuga and Sweller, 2015); the worked examples effect suggests that, by studying problems that have already been worked through to some degree, learners' cognitive load is reduced; finally the expertise reversal effect refers to the notion that instructional techniques that are used successfully with novices are not necessarily as impactful or efficacious with more experienced students (Paas, Renkl, and Sweller, 2003). The video tutorials on Hegartymaths always feature moments where the student is expected to "pause and have a go" when a 'small-step' has been shown, before the questions posed are answered and explained by Colin Hegarty. This feature occurs prior to the task quiz. This can be problematic for several reasons, but a main issue is that learners either skip this part out entirely, or they do check their understanding properly but realise they have not adequately grasped the process. Again, it must be reinforced that Hegartymaths is not intended to replace the teacher and teachers should plan for the latter scenario and have several approaches ready for how to tackle this.

Learners and the learning process are unpredictable, idiosyncratic and non-uniform (Brown et al., 2018). Despite the structures imposed by education systems, there is no guarantee that learners will progress in a linear fashion, reaching academic milestones at the same time as their peers. As such, challenging concepts must be revisited – often repeatedly - after their initial launch, before learners have a robust grasp of them (Denvir and Brown, 1986; Brown et al., 1995; Pirie and Kieren, 1994). This then positions the teacher in a fundamental role in the teaching triad as classroom learning is the desired and required outcome of the multitude of interactions between the three agents - the teacher, the learner and the mathematics (Kilpatrick, Swafford and Findell, 2001). Variance in the learners' contexts must not be overlooked either.

2.2.8 Mathematic pedagogic approaches

The major approaches to teaching mathematics explored within the literature are: explicit and direct instruction; mastery learning; and inquiry-based learning. Before examining these in more depth, it is important to consider some literature concerning the pedagogical aspects of generic teaching of mathematics. These are: addressing misconceptions, providing feedback, learning collaboratively and, specifically, implementing meaningful class discussions. The end of this section concludes with an exploration of Hegartymaths' place amongst these approaches, which will provide a range of possible explanations for the findings of all my research questions in the discussion chapter.

Mathematical misconceptions are a product of prior learning experiences that take place in a setting with strong experiential foundations (Smith, diSessa, and Roschelle, 1994), wherein the learner has applied the misconception within a limited context in order to explain or make sense of something. As such, many misconceptions are grounded in a functional, purposeful knowledge basis which can then prove problematic to challenge and overturn. When the restricted context in which the misconception arose is then expanded to incorporate more mathematical concepts, learners encounter unforeseen challenges. It follows that teachers need strategies by which to uncover and confront misconceptions, as well as to devote time to investigating how the misconception was internalised in the first instance so as to prevent the process from repeatedly happening (Smith, diSessa, and Roschelle, 1994).

Feedback is commonly understood to mean the provision of information concerning elements of one's performance or understanding (Hattie and Timperley, 2007), while formative assessment is conceptualised as the practices wherein the information collected concerning performance is then used to enhance or modify subsequent teaching and learning approaches (Hattie and Timperley, 2007). Some studies report that feedback practices can have a negative as well as a beneficial effect on learning (Hattie and Timperley, 2007).

Collaborative learning is defined in a range of ways, from the more open-ended description of working with or alongside fellow students in group settings (Lee, 2000) to the more specific idea of small, mixed-ability groups working together towards a shared goal (Slavin, 2007; 2008) (Othman, 1996). Collaborative learning has also been considered to embody whole-class, collective teamwork (Haas, 2005) as well as peer-tuition.

Establishing and facilitating effective classroom talk is not simply a case of creating opportunities for discussion in the learning environment. Generically, classroom talk predominantly follows the initiation-response-evaluation (IRE) paradigm, although this does not necessarily mean that all the learners in the group are being targeted to contribute (Kyriacou and Issitt, 2008) as they might in a dialogic teaching context wherein the questioning and discussion is a carefully-structured and continuous back-and-forth process between the learners and their teacher, with the ultimate aim that all students contribute equally (Alexander, 2010; 2017). Further, the quality of classroom talk in mathematics settings has been seen to be enhanced by increasing the 'wait time' given to the students prior to accepting their answers (Tobin, 1986; 1987), particularly when asking learners higher-order questions.

Improving classroom dialogue in mathematics education goes beyond simply setting up more opportunities for student talk; an integral aspect of improving the quality of classroom talk is the teacher's ability to actively listen to their learners' explanations and move from an evaluative to an exploratory stance, whereby they are not listening to merely judge the correctness of the responses but to understand the pupils' mathematical thinking and handling of concepts (Kyriacou and Issitt, 2008; Walshaw and Anthony, 2008). As such, educators need to actively teach pupils how to talk and how to listen by establishing systems and norms for what is acceptable in their classroom (Walshaw and Anthony, 2008). Finally, talk as part of mathematics learning is thought to be important as it helps make students' thinking a visible process and, as a result, allow for more effective critique (Walshaw and Anthony, 2008).

2.2.8.1 Explicit teaching and direct instruction

Explicit instruction is an umbrella term for the teaching practice that involves, firstly, demonstration of a concept or process by the educator, followed by guided practice with the teacher as mediator and ultimately leading to them being able to independently practice (Rosenshine, 2008). It differs to inquiry-based learning in that explicit instruction front-loads the process with explanations and worked examples of key ideas and techniques that equip students with the know-how before they then tackle a similar problem. Inquiry-based learning typically confronts learners with a problem to solve without giving them insight into what might be an appropriate approach to use (Rosenshine, 2012). For explicit instruction programmes in general, there is evidence to suggest that there is a larger effect on attainment (Gersten et al., 2009). Direct instruction (DI) is one permutation of explicit instruction that has received a great deal of attention in the research field. DI is a complete curriculum provision that, broadly, encompasses the breaking down of tasks into small steps that are meted out rapidly and with rigid stages of progression. Assessments are done before and after the units of learning to establish pupils' levels of mastery, and teachers are issued with scripts for much of the lesson content. DI is focused on the modelling of methods that is then supported with a high volume of practice and has faced criticism for an overly regimented structure that is considered restrictive due to the emphasis on rote learning, the extensive testing and the alleged passivity of the learners and - in some senses - the teacher too, due to the scripted element (Borko and Wildman, 1986) (Brown and Campione, 1990). In defence of DI, it has been suggested that the instructional sequences that form the basis of the learning are so deeply rooted in research that they heighten the efficiency (McMullen and Madelaine, 2014).

Medium to high effects of DI on mathematics attainment have been reported (Gersten et al., 2009; Dennis et al., 2016;) in addition to evidence that this mode of teaching is especially helpful for pupils with mathematics-specific learning difficulties (Chen, 2004; Haas, 2005). It should be noted however that there is a large range of effect sizes when it comes to research into DI. DI has, on the one hand, been found to have similar effect sizes to other teaching strategies that could be considered constructivist, including guided discovery (Jacobse and Harskamp, 2011), yet on the other hand there is evidence to suggest that unstructured modes – such as unguided discovery – are not as effective (Mayer, 2004). There are, however, gaps in the literature pertaining to how DI might be blended or counterbalanced with other pedagogical approaches.

2.2.8.2 Mastery learning

Mastery learning, although similar to direct instruction in structure, is different in the sense that learners are offered a variety of different approaches and strategies as part of their instruction (Bloom, 1968). The phrase ‘teaching for mastery’ has recently been adopted to describe how both classroom practices and school organisation combine in order for all learners to acquire a rich, deep understanding of mathematics that is both secure and adaptable (NCETM, 2016). Effect sizes for mastery approaches in mathematics education tend to be high (Guskey, and Pigott, 1988; Kulik, Kulik, and Bangert-Drowns, 1990; Rakes et al., 2010), most notably at primary level (Guskey and Pigott, 1988) and possibly in the context of being a low-attainer (Brown et al., 2018). Other factors that appear to result in a large effect size are the contexts wherein students have to move through material at the pace set by the educator and not the learners themselves (Kulik, Kulik, and Bangert-Drowns, 1990) and the fact that learners have to have achieved a high score on unit assessments prior to moving on, as well as the fact that they receive feedback (Kulik, Kulik, and Bangert-Drowns, 1990). It should be acknowledged that effect sizes for mastery learning may be skewed by instrument design, length of intervention and the nature of the feedback (Slavin, 1987; Brown et al., 2018). Mastery learning - in much the same way as direct instruction – is seen to be effective in targeting highly specific knowledge and processes, and proponents of this approach assert that it encompasses both procedural fluency and conceptual knowledge, where they are seen to support each other (NCETM, 2016). What research into mastery learning has yet to address, is how this educational approach enables learners to develop metacognitive skill or to forge connections between different mathematical domains in order to solve novel problems. As such, mastery learning has been seen by some as playing a role as a supplementary and not a central mode of education.

2.2.8.3 The effects of inquiry-based learning and related approaches to teaching

As mentioned previously, it has been argued that inquiry-based learning (IBL) is less effective than explicit instruction. This is considered to be the case because IBL approaches to teaching position the novice learner as the expert in a scenario where they might not be equipped with the knowledge required to solve the problem (Kirschner, Sweller, and Clark, 2006). It has also been argued that the cognitive load placed on the learner in this context may be counterproductive to the learning process, most notably if the learners are at a novice stage or are low-attaining (Kirschner, Sweller, and Clark, 2006). IBL is considered to be a student-centred, and often collaborative, teaching approach where the learner takes control of which clarifying questions to ask and which resources to draw on, so as to be able to explore the problem before navigating their way to a solution. IBL approaches to teaching are thought to hone students' communication skills, in addition to making the learning process more engaging and more memorable due to its active nature (Hmelo-Silver, Duncan, and Chinn, 2007). Further refutes to criticisms of IBL assert that this approach is not unguided, but does in fact incorporate scaffolding that works to significantly decrease the learner's cognitive load (Hmelo-Silver, Duncan, and Chinn, 2007). At the heart of teaching problem solving is the hoped-for outcome that learners are then able to transfer their knowledge to different, novel scenarios; reaching the solution itself is not the ultimate aim. It follows that IBL approaches that incorporate worked examples may be helpful in schooling the learners in the concepts and strategies involved in solving a problem.

It has been found that school and teaching effectiveness does not appear to depend on one approach in particular (Scheerens et al., 2007). When student-centred – or constructivist – teaching was compared to structured, direct teaching and teacher-centred approaches, similar, small effect sizes (around 0.1) were found for all types (Scheerens et al., 2007).

2.2.9 Teaching and learning in the broader areas of mathematics

The research field seems to be limited in terms of how to teach students differently for specific topics, otherwise known as the 'technicalities of teaching' (Nunes, Bryant and Watson, 2009). The following section describes what the findings from current literature indicate about teaching specific topics of maths, including: Number, Algebra, Geometry and Probability and Statistics. This examination of the literature will be of most importance in my attempt to answer my second research question: *Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?*

2.2.9.1 Algebra

It has been argued that algebra is the fundamental language of mathematics and that it is essential knowledge (Silver, 1997), and there has been an increased focus on providing secondary school pupils with these essential skills for life in today's knowledge-based economy (Midgett and Eddins, 2001). A significant amount of evidence asserts that students struggle learning algebra (Hart, 1981; Hodgen et al., 2012). Students tend to answer questions well when they realise what mathematical topic they are being presented with, and which tools and methods they should harness to solve the problem; algebraic topics lend themselves well to routine questions pupils have seen before, although the literature argues that a predominance of drill and practice in approaches to teaching algebra might not facilitate algebraic understanding (Rakes et al., 2010). The main conceptual challenges students face are cited as (Brown et al., 2018):

The abstract nature of algebra: By making generalisations using numbers and symbols when forming expressions or equations, students thinking algebraically means that they think abstractly (Nunes et al., 2009). This may require learners to process many pieces of complex information simultaneously, which increases cognitive load (Star et al., 2015) and subsequently may prove problematic for their capacity to solve the problem.

The meaning of algebraic symbols: Expressions using letters to represent numbers, variables and constants lead to difficulties and misconceptions regarding their interpretation that can lead to misunderstandings of their meaning (Küchemann, 1981; Nunes et al., 2009), and many errors do occur from weak understanding of the notation (Stacey, 1989; MacGregor and Stacey, 1997).

The structural characteristics of algebra: The structures of algebra are derived from number relations (Kaput, 2008). A learner's failure to grasp algebraic concepts has also been explained by the significant gap between arithmetic and algebra (Filloy and Rojano, 1989; Linchevski and Hersovics, 1996), and when students simply attempt to memorise rules of algebra without fully understanding them, they often misapply these rules or remember them incorrectly (Nunes at al., 2009).

Both procedural and conceptual pedagogical approaches for the teaching of algebra are advocated strongly in the literature (Haas, 2005; Rakes et al., 2010; Star et al., 2015), although there still appears to be significant emphasis on favouring a procedural approach within the teaching profession, despite findings in the literature that point to the benefits of both modes (Stigler and Hiebert, 1997; Hiebert, 2003). The use of technology through computer-aided instruction was promoted (Rakes et al., 2010) and also cited as having a positive effect, but negligibly so, although the implication was not that teachers should avoid the use of technology (Haas, 2005). A stronger case was made for the use of both explicit teaching and problem-based learning as opposed to the slightly less positive, although significant, effects of cooperative learning and manipulatives (Haas, 2005), although the difference between the approaches of explicit teaching and problem-based learning were unclear and problematic in the meta-analysis as they could encompass each other (Rakes et al., 2010).

2.2.9.2 Number and calculation

Although there is sufficient research on how students learn number and calculation in general (Fuson, 1992) and their associative common misconceptions (Hart, 1981; Ryan & Williams, 2007), it is surprising that there are no meta-analyses specifically addressing the teaching approaches of multiplicative reasoning, number sense, estimation, or general calculation (Brown et al., 2018).

In a study that targeted both pupils with SEN and low-performing students for their knowledge of basic facts, interventions comprised of direct, mediated and self-instruction were compared for students of different ages. When there was sufficient provision of verbal prompts, self-instruction was observed to be more effective than direct instruction, although direct instruction was still seen as the most effective method for learning basic facts without these prompts. Interventions were also more effective for older pupils and peer-tutoring was found to be less effective than not (Kroesbergen & Van Luit, 2003). When comparing instruction prescribed by the teacher as opposed to a computer, it was reported that, although computers can play a role in improving knowledge after positive results, the significant difference between outcomes suggests computers cannot replace instructions given by a teacher. This finding sits well with the implementation design of Hegartymaths, as the method of teaching through computers has been seen to teach content of number and calculation successfully to an extent, and the platform was not designed to replace the teacher but to supplement the classroom learning.

A further study strongly advocates that interventions for students struggling with mathematics are most effective when they are direct and teacher-guided using explicit instruction that is systematic (Gersten et al., 2009). Although not specific to number and calculation, these interventions have been recognised as particularly relevant to the teaching of calculation (Brown et al., 2018).

Another interesting recommendation centred on the time devoted to student practice. Around ten minutes should be factored into the learning sequence after every intervention, for students to practise content learnt and become fluent in retrieving derived facts (Gersten et al., 2009). This resonates well with the structure of Hegartymaths, where there are opportunities to practise what has been learnt when the virtual teacher prompts the user to “pause the video and have a go”, before going through the problems together for students to be able to check for their understanding.

2.2.9.3 Geometry

Systematic reviews did not identify many studies that examined the efficacy of teaching interventions (Clements & Battista, 1992; Bryant, 2009; Frye, et al., 2013) specifically for geometry and spatial reasoning. Established in 1871 in the UK, the Association for the Improvement of Geometrical Teaching is the oldest known association of teachers, which we now know as The Mathematical Association; this organisation's legacy serves to illustrate how long there have been efforts to improve geometry teaching.

Dynamic Geometry software, such as Cabri and Geogebra, were found to be significantly successful for the teaching of geometry (Chan & Leung, 2014), where there is strong potential for the successful teaching of geometry through technology and computers (Clements & Battista, 1992). Although this is also potentially an optimistic finding for online learning, the software packages mentioned in the studies vary significantly from the technology that is currently used in the Hegartymaths video tutorials; the unique structure and strategy behind the Hegartymaths platform has not been researched, despite its burgeoning popularity in English schools.

Teaching concepts rather than procedures is a feature in the recommendations, particularly the conceptual basis of measurement (Bryant, 2009). Further, the role of diagrams was considered key in the learning of geometry, as were representations and manipulatives (Clements & Battista, 1992). However, for successful teaching of the concepts relating to these diagrams, teachers should consider varying the orientation (Brown et al., 2018), which would also restrict some of the common misconceptions that arise from not orientating shapes (Dickson, Brown and Gibson, 1984). Diagrams have also been seen as a necessary way to entwine the 'spacial and deductive' aspects of geometry (Watson, Jones and Pratt, 2013).

'Only just' examples and 'very nearly' non-examples are usually in the form of diagrams where one adjustment makes the examples non-examples, and vice versa. These are an advocated approach to teaching conceptual understanding of geometry (Askew et al., 1995), and students should be encouraged to create their own examples (Watson and Mason, 1998; Prestage and Perks, 2001). Encouraging students to be critical of their own work as well as of their peers' work is also essential practice for pupils to realise that deductive reasoning is more complex than stating a belief and checking to see if this holds true, although this practice is considered difficult for teachers and requires a careful approach (Royal Society, 2001).

2.2.9.4 Probability and statistics

Again, many reviews highlighted how limited research into the effect of teaching interventions is within the topic of probability and statistics at secondary education level (Shaughnessy, 1992; 2007; Jones, Langrall and Monney, 2007; Bryant and Nunes, 2012). It has been argued that the nature of statistics is quite different from mathematics and that it is better suited to sit outside of the mathematics curriculum

(Smith, 2004). Some of these arguments are made because statistical reasoning, unlike mathematical reasoning, is not validated through acontextual logic and it has been argued that statistical knowledge is set in the contextual domain, which can be justified through the philosophical stance inferentialism (Brandom, 2002).

Purposeful tasks that give the statistics meaning for the student are important for contextual understanding (Ben-Zvi, 2006; Makar and Rubin, 2009) and research into an active graphing approach is an example of how this can be done (Ainley et al., 2000), but exploratory data analysis (Tukey, 1997) will not happen in classrooms unless the curriculum changes to encourage teachers of statistics to adapt and adopt a statistical enquiry approach (Watson, 2013).

2.2.9.5 Is Hegartymaths more suited to the teaching of a specific mathematical area?

After reviewing the literature, I am not much closer in answering this question than I was before doing so. I know that my personal experience has led me to believe that Hegartymaths is better suited for some topics more than others, but while the literature does describe the difficulties pupils face within each area, I could not find comparisons in terms of whether certain areas of mathematics are better suited to particular teaching pedagogies. What is clear however, is that this short analysis of the various topics has highlighted that there are nuances between areas of mathematics that lead to pupils encountering a variety of contrasting difficulties, and these will offer some possible explanations of my findings in the discussion chapter.

Chapter 3: Methodology

3.1 Introduction

This chapter discusses the research methodology and methods I have used for examining my research questions and for the associated empirical work reported in my results. I begin the chapter with my research questions, giving a brief background of how these came to fruition. I then continue by discussing the various research methodologies that were available to me in attempting to answer my research questions. I argue that, although I see merit in constructivist epistemology, I use the mixed-methods chosen, both quantitative and qualitative, through the lens of post-positivism, and therefore from an objectivist epistemological standpoint. I also define and explore the use of 'big data' so as to provide a way in which the Hegartymaths analytics can be organised and related to GCSE performance, which offers an addition to the existing literature from a methodological point of view.

Looking at each of my research questions in turn allowed me to explain my sampling strategies required for my empirical work and the strategies I employed for each question, which have significant differences although they are connected in the sense that they view Hegartymaths from different angles. The procedures are also documented in each case with the associated limitations these have in relation to the post-positivist paradigm chosen.

The chapter concludes by considering the ethical implications as well the claims of validity and reliability of the research.

3.2 Research questions

A good piece of research starts with the research questions as opposed to playing to the methodological strengths of the researcher (Crotty, 1998)). Before applying to the EdD, I had already been interested in the implementation and impact of blended learning for quite a few years. As such, I observed classroom strategies in schools in both the UK and the USA, looking at how various approaches to technology were used to change teaching and learning, both from a pedagogical point of view and the opportunities it gives to alter the structure of a traditional classroom. This is a field that is still of very great interest to me and one that inspired me to apply for the EdD programme.

As a result, I have been using it as supplementary to my own teaching, as do a large proportion of mathematics teachers in the UK (approximately a third). Since I began my teaching career in 2006, I have not found there to have been a more significant change to maths teaching across the UK than that enabled by Hegartymaths; this is most certainly the case for my own teaching practice. There has been a wealth of anecdotal claims of the value Hegartymaths has played in students' maths education and detailed below are a few of these testimonials of the many that can be found that teachers, parents and students have written on the Hegartymaths website (https://hegartymaths.com/success):

> *"HegartyMaths is the first maths resource I have come across in teaching that benefits both the high fliers and lower end as the topic range is so large. The instant feedback and help videos have been a valuable resource for students since I first started using HegartyMaths back in November 2015. HegartyMaths has encouraged both independent and guided study with most students completing a task a day which could never be achieved through a standard worksheet and teacher marking. HegartyMaths can be used as a fantastic retrieval task selecting topics both recently covered and previously covered in the last month or years"*
>
> (Mr Roberts, Maths teacher @ The de Ferrers Academy)

> *"I think HegartyMaths is a fantastic resource, it really allows me to support with homework - we watch the videos together, they are excellent". "I think it is a good system - I like how you can check how long they spent on the homework and if they have watched the videos. As a parent, I would be prepared to pay for it!"*
>
> (Happy parent)

> *"I was in the bottom set in maths in my school. I started doing lots of HegartyMaths and got better at maths. My teacher saw my progress in HegartyMaths and combined with my end of term assessment I was moved up two sets"*
>
> (Rohan, Student @ Heston Community School)

In 2014, the UK prime minister David Cameron presented Colin Hegarty, the founder of Hegartymaths, with both the Outstanding Use Of Technology in Education Award (https://www.mylondon.news/news/local-news/wembley-maths-teacher-presented-tech-8010730) and the prestigious Pearson Teacher of the Year Award (https://www.kilburntimes.co.uk/news/education/brent-teacher-honoured-by-prime-minister-david-cameron-1-3824267) before Colin's name appeared in the final top ten shortlist of the Global Teaching Prize in 2015 (https://www.bbc.co.uk/news/education-35592440).

Although I have seen the value of the platform for the students, their parents and teachers at the school I work at, I consider these to be somewhat anecdotal without having read any published research about Hegartymaths. My research questions concerning Hegartymaths could have focused on just the students at the school I work at, my own students, particular classes or certain groups of students and there are various methodologies and methods I could use to do this, both qualitative and quantitative, which can start from either an objective, constructive or subjective epistemological start point.

As this is the first research into Hegartymaths I am aware of, I wanted to start my research with as broad a scope as I could, in order to answer a simple question as well as possible: how good is Hegartymaths?

From a teacher's point of view it is essential that this should be linked to pupil outcomes. In the UK, we currently measure outcomes using GCSE examinations so I decided to alter and narrow my first research question to: *To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE?*

Mathematics education, even at GCSE level, is categorised into several areas and major exam boards. AQA (https://filestore.aqa.org.uk/resources/mathematics/specifications/AQA-8300-SP-2015.PDF) and Pearson Edexcel (https://qualifications.pearson.com/content/dam/pdf/GCSE/mathematics/2015/specification-and-sample-assesment/gcse-maths-2015-specification.pdf) categorise these into six areas: *number, algebra, ratio, proportion and rates of change, geometry and measures, probability, and statistics*.

In addition to these, the assessment objectives (to see a more substantial definition of assessment objectives (AOs), see section 4.2.3), set by Ofqual are the same across all GCSE Mathematics specifications and all exam boards:

AO1 – Use and apply standard techniques
AO2 – Reason, interpret and communicate mathematically
AO3 – Solve problems within mathematics and in other contexts

Hegartymaths uses the same format for all topic areas of mathematics. A video tutorial teaches the content, where pupils can engage with it by pausing the video; pupils can then try to answer some worked examples after these have been modelled within the video, before attempting to answer the questions generated by the quiz appropriate for that topic area. As a teacher who teaches the various topics and assessment types in different ways within my classroom, I am interested to see if this one-size-fits-all approach works equally successfully for all topics and assessment objectives. My second research question takes a closer look at how useful Hegartymaths is for pupil outcomes according to these: *Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?*

There are various different ways that teachers use Hegartymaths: as a learning tool on its own; a revision tool; for homework both in the traditional sense and as part of a flipped learning model wherein unknown topics are studied on Hegartymaths prior to the lesson where the teacher then explicitly teaches them in the classroom. My final question investigates if there are certain ways in which a teacher uses Hegartymaths that are more beneficial for the outcomes of pupils: *How is Hegartymaths used in the most successful schools?*

3.3 Research paradigm

Epistemology deals with the nature of knowledge (Hamlyn, 1995) and how adequate and legitimate these knowledge claims are by providing a philosophical grounding (Maynard, 1994). After deciding on the topic of my research, I naïvely fell into the trap many scientists have done before me, by formulating problems in a way in which I am especially skilled (Pedhazur, 1982). My background in engineering does lend itself well to the objectivist train of thought that leads to a positivist paradigm of research, and this was set to be my starting point. However, my experience in teaching is more than enough to know that a positivist scientific experiment was out of the question, both from the realistic point of view that there are too many variables to control and also from an ethical standpoint in that the research design could potentially disadvantage the pupils who do not receive the conditions that are thought to lead to preferable outcomes. As such, I looked towards different epistemological viewpoints to recognise where I stand.

"Objectivism is the epistemological view that things exist as *meaningful* entities independently of consciousness and experience, that they have truth and meaning residing in them as objects ('objective' truth and meaning, therefore), and that careful research can attain that objective truth and meaning" (Crotty, 1998, p. 5-6). If I am to apply this to Hegartymaths, the object I wish to research, I must see this online platform as something that has meaning and therefore meaningful reality, and that as such it exists apart from the operation of any consciousness. If I were to look at Hegartymaths from an objectivist educator's lens, I could devise an argument that it is a vehicle to transfer knowledge, which consists of correctly categorising and understanding mathematical concepts before correctly grasping objective connections between these concepts and categories (Lakoff, 1987).

Instructional design models based on objectivist paradigms emphasise designing instruction in several steps (Dick and Carey, 1996; Gagne and Briggs, 1974; Smith and Ragan, 1993; Wagner, 1990):

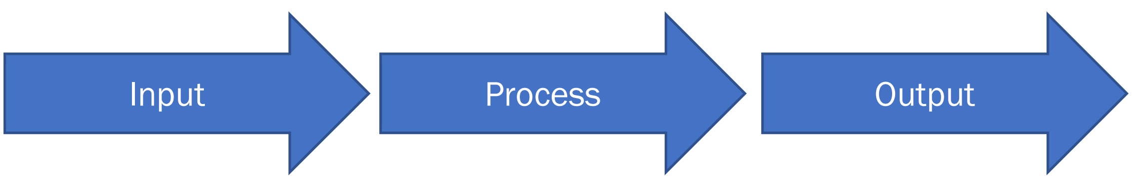


Figure 3.1: The input-process-output model of instructional design

The input here is the course content found in Hegartymaths, which has been analysed by the distance educators (the Hegartymaths team) and broken into small chunks with performance objectives attached to each video tutorial (Vrasidas, 2000). The process is the instructional videos, and the output in this case could be the quizzes on Hegartymaths that follow every video tutorial, which evaluate the objectives to a certain extent.

In my experience, I believe this to be flawed. While there have been various occasions where I have set a series of video tutorials and tested this from a distance, there is a significant argument to suggest that this model is not the best approach. In these instances I valued the learner-teacher and learner-content interaction, the two most valued interactions by an objectivist distance educator, and restricted any real value in learners' interactions with peers (Vrasidas, 2000). On these occasions, I chose to answer questions posted online, only until pupils were able to score above 90% on the quizzes as a class average, which they did eventually. This was useful as it saved me valuable time teaching concepts I believed were easily accessible for students to learn without their teacher. This in turn allowed me to work on more complicated concepts in class, and not lose precious teaching time on what some might perceive to be the basics.

Although I believe there is still merit to this, the reason I believe it is flawed is that the process by which students receive instruction is of great importance and this cannot be done effectively from a distance. Pupils in my class grasp concepts much more efficiently and fully when they are able to interact with their teacher and peers in a class setting. They all benefit from these group and individual interactions and my students consistently performed better in tests on the harder-to-grasp concepts learnt in class, as opposed to the less complex ones I selected for students to learn online. The classroom scenario allowed me to immediately jump to challenge any emergent misconceptions regarding the new learning, provide a range of models and non-examples and allow students to collaboratively problem-solve, therefore consolidating secure learning.

A further reason that pupils didn't perform as well on the later tests - specifically on the topics learnt online - is that the learning of a specific topic, which is then quizzed straight after, doesn't allow the learner to know when to apply this knowledge. The tests had several questions that required pupils to apply knowledge of several topics. Hegartymaths is not designed in a way to allow pupils to practise applying their knowledge in different scenarios. Pupils practised similar questions over and over again in their attempts to achieve 100%, without having to think 'what topic is this?' and 'what knowledge do I need to apply here?'. They became fluent in specific questions, but mathematics is more than just fluency and exam boards (rightly) test problem solving skills and application too, which are not hugely prevalent in Hegartymaths.

Today, "virtually all contemporary approaches to teaching and learning have a constructivist cast" (Perkins, 1998, p. 55) and the predominant goal of instruction is not one that tries to map one single external reality into the mind of the learner (Vrasidas, 2000). The personal constructivists claim that knowledge is constructed in the mind of the learner (Piaget, 1970; Von Glasersfeld, 1989), while the social constructivists believe that knowledge is constructed in communities through social interaction (Brown, Collins, Duguid, 1989; Kuhn, 1996; Lave and Wenger, 1991; Vygotsky, 1978). Specifically to maths education, "mathematical learning should be viewed as both a process of active individual construction and a process of enculturation into the mathematical practices of wider society" (Cobb, 1994, p. 13).

This standpoint means that a constructivist approach is significantly different to the objectivist model of distant education course design, as seen in Figure 3.2. The constructivist paradigm does not have rigid and separate phases; instead it has three major phases that overlap and are ongoing.

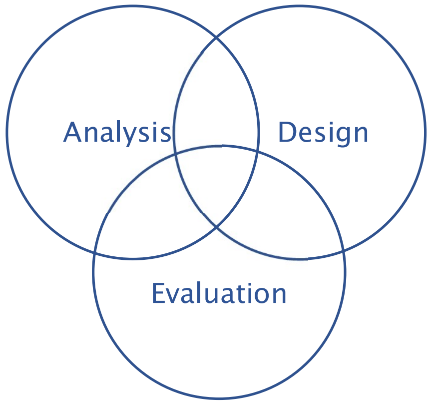


Figure 3.2: The constructivist approach to instructional design (Vrasidas, 2000)

Seen in this way, content areas do not have the same strict boundaries as they did in the objectivist model. A teacher might be able to define a major content domain, such as Hegartymaths, but as it is an online platform clear-cut boundaries of relevancy are impossible to set (Vrasidas, 2000), and the interactive nature of the web allows students to explore other resources to make knowledge meaningful to them (Dede, 1996; Jonassen, 1996).

The goal for the constructivist educator has now shifted from the objectivist goal that intended Hegartymaths to teach specific topics. Instead, the aim is to provide opportunities that can guide learners to think and act like experts (Bednar, Cunningham, Duffy and Perry, 1992; Brown, Collins and Duguid, 1989; Resnick, 1987), where the learner has control to pick and choose what they feel is relevant and useful (Baynton, 1992; Moore, 1994). The teacher shifts from being seen as an authoritative, even didactic figure to one that that is more of a coach or almost partner in the learning process.

Resultantly, I recognise merit in this approach and my practice in the classroom reflects this constructivist approach. I arrange the pupils in my classroom in groups and design tasks that encourage peer interactions in all lessons other than tests. I do not subscribe to the view that there is one correct way to understand a concept and I insist on pupils looking for multiple ways in solving a problem. I consider myself a constructivist teacher that does not expect that all the students will learn the exact same thing (Cziko, 1989) and place major importance on interaction with peers, debate, anchored instruction and cooperative learning (Bransford et al., 1990; Brown, Collins and Duguid, 1989; Lave and Wenger, 1991; Spiro et al., 1992). Within my classroom, I use Hegartymaths in ways that are consistent with the constructivist approach, such as displaying questions students posted online and asking groups to discuss and work towards the answer, and I believe I could design a research project that would seek to uncover how Hegartymaths can aid teachers help pupils learn in a constructivist way through analysing my own classes in detail and applying interpretivist methods.

The constructivist approach has been criticised however, and one of the main weaknesses cited is its inability to evaluate learning (Prawat and Floden, 1994). If the performance objectives aren't clearly defined to begin with, the teacher cannot be expected to know what to teach, let alone evaluate and assess student learning. Researching Hegartymaths from a constructivist epistemological position would have profound issues, as I would have to use the platform in a way it was not intended. Colin Hegarty, the founder of Hegartymaths, does not promote that the platform should be used as a substitute for the teacher and he is often cited as referring to it as ‘the cherry on top of the cake’, the ‘cake’ being good and consistent teaching within the classroom context. Having said that, from a constructivist point of view, it is impossible to restrict pupils in terms of how they will use the platform and many do use it to learn material a topic at a time, with clear-cut performance objectives, an approach that is much more aligned to objectivism. Therefore I have reached the conclusion that I believe there are several ways one could approach research into Hegartymaths, either from an objectivist or constructivist starting position.

There has been discourse around the adoption of multiple paradigms within a single research project. Some researchers believe that it is impossible to combine multiple paradigms because they adopt contrasting ontological and epistemological positions (Angouri, 2018; Nudzor, 2009) and where one form or another of constructionism can be found or claimed in most perspectives, those representing positivism and post-positivism paradigms are objectivist by definition (Crotty, 1998). Post-positivists believe in a single reality whereas interpretivists believe that there are multiple realities, which in turn suggests the two researchers should go about obtaining knowledge very differently. Interpretivists enter the social world, interacting with individuals who have had different experiences and attempt to interpret these to understand a phenomenon (Nudzor, 2009). Post-positivists resist these interactions as they use tests and measurements to uncover the reality. In contrast to this, other researchers believe that combining assumptions from multiple paradigms is encouraged in a single piece of research as this reveals different aspects of social 'reality' (Angouri, 2018; Creswell, 2014).

Whatever my choice of primary method is, it is more than likely that the chosen topic of research will involve numbers, at least at the outset, before a smaller group can be sensibly selected for a more detailed study (Gorard, 2001). Narrowing down the research and placing it in context was not a possibility with Hegartymaths, as there hasn’t been research into the efficacy it, or other online platforms, has on teaching mathematics using a large data set that I was able to access.

The value of educational research as a contribution to the improvement of education, has been called into question (Hargreaves, 1997; Hillage et al., 1998; Tooley and Darby, 1998) and there are few studies which individually or collectively contribute systematically to the development of a comprehensive body of high-quality evidence about pedagogy (Millett, 1997). Since I entered the profession in 2006, the only two pieces of research that have truly become mainstream, and that I have been able to discuss with other practitioners, have been Rosenshine’s paper on the principles of direct instruction (1978) and the Lemov techniques. Recently there has been a large-scale movement towards these schools of thought, and many schools are designing their teaching and learning strategies so that they are centred on principles derived from Rosenshine and Lemov’s work. The two main reasons cited for this chasm between theory and practice are: firstly, a lack of real-world relevance of much research and secondly, a system-wide gap in expertise in conducting large-scale studies, especially field trials derived from laboratory experimental designs. Further, much educational research in the UK is small-scale, non-replicable or interpretative, leading to insecure conclusions. Most educational researchers are now predominantly qualitative in approach, but politicians and funders want to see trends revert back towards a more balanced range of skills that could start from a consideration of 'truth' (Bridges, 1999) and a return to a political arithmetic tradition (Mortimore, 2000).

This call for more scientific experimental research in education, coupled with my fortunate position in being able to gather data leading to a large-scale project (which can, from the outset, use a quasi-experimental design to study the entire population instead of sampling) is very appealing. Research of this nature at this scale has not been conducted on any online platform at the time of writing and so I have chosen to adopt assumptions from the post-positivists, which lend themselves well to seeking a cause-and-effect relationship when analysing the use of Hegartymaths in relation to GCSE outcomes. The knowledge I will obtain through the post-positivist lens will therefore focus mostly on the product rather than the process. I still believe that interpretivists can shed additional light on the research topic (Teddlie and Tashakkori, 2009) and I explain this further when discussing the limitations of the research, one research question at a time.

The methods I have used are both qualitative and quantitative to serve specific purposes; this should not be problematic although what does concern me at this stage of the research, is attempting to be both objectivist and constructivist simultaneously (Crotty, 1998). I deliberately say this at this stage of the research though, as I hope that the results of this study will inspire me to take a closer look, where I can separate from the objectivist approach and adopt more interpretivist methods.

It should be noted that if we strive to be consistently objectivist, we will distinguish scientifically established objective meaning from subjective meanings that people tend to hold and that at best 'reflect' or 'mirror' or 'approximate' objective meanings. It follows that it will be accepted that these subjective meanings are important in people's lives and we may develop and implement qualitative methods of determining what those meanings are. This is epistemologically consistent. The consequence of this however, is that it renders people's everyday understandings inferior - in an epistemological sense - to more scientific understandings.

The 'scientific method', 'quantitative research' and 'empirical science' are all ways that post-positivism has been referred to (Creswell, 2014). The predominant philosophy for quantitative research in human sciences is post-positivism (Teddlie and Tashakkorie, 2009), which evolved after positivism was criticised for upholding the belief that there is absolute truth and that knowledge is based on secure foundations. Although post-positivists believe that all measures and observations are fallible (Creswell, 2014), they do believe the world is governed by laws, and that the social world is no different, which is best explained in terms of a determinist philosophy of cause and effect (Creswell, 2014). Based on that presumption, post-positivists believe that humans' actions are explained by the social norms to which they have been exposed (Creswell, 2014). In essence, the post-positivist researcher's role is to uncover the laws that govern human behaviour (Creswell, 2014). An investigation starts with theories and hypotheses before measurements and observations test these theories. Additional tests and revisions can then be conducted for verification of such theories (Creswell, 2014).

3.4 Methods and assumptions

It should be acknowledged that, as researchers, the acts of observing, interpreting, reporting, and everything else undertaken as part of the investigative role, are imbued with a range of assumptions. These assumptions tend to be about human knowledge and pre-conceived ideas about realities encountered in our human world. Such assumptions inevitably influence the meaning of our research questions, the purposiveness of research methodologies and the interpretability of research findings. Without unpacking and exploring these assumptions and clarifying them, it becomes impossible to truly know what our research has been or what it is now saying (Crotty, 1998). As a result, I have separately expounded the methods used, the assumptions made and the corresponding limitations according to each of my research questions, detailed below.

3.4.1 To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE?

A quantitative approach has been used with a large dataset to find out how effective Hegartymaths is. This includes both examining the various ways Hegartymaths is used and determining which specific topics and types of questions are best suited for these online video tutorials and relevant practice. A quasi-experimental approach is necessary in attempting to determine if there is a cause-and-effect relationship between pupils using Hegartymaths in United Learning schools and GCSE outcomes, as well as this being a common design in studies where individuals aren't randomly assigned (Creswell, 2014).

An experimental design is used to investigate causal relationships (Shadish, Cook and Campbell, 2002) where a test under controlled conditions to examine the validity of a hypothesis is conducted (Muijs, 2011). In social work, it is typically used to identify the effect on subjects after receiving a particular intervention (Thyer, 2012). There are two types of experimental design: randomised experiments and quasi-experiments (Reichardt, 2009).

Quasi-experimental research is similar to experimental research; they both manipulate an independent variable on dependent variables, and both observe subjects in a controlled environment (Verma, 2015). The difference is that in a quasi-experiment there is no random assignment to groups (Reichardt, 2009).

Due to ethical and practical considerations, randomised experiments are not common in educational research, where quasi-experiments are often used (Reichardt, 2009).

This study investigated a causal relationship within a natural setting and it employed a quasi-experiment design without including pre-tests and post-tests or choosing which pupils were given the intervention of Hegartymaths. The control group are the pupils who do not use Hegartymaths and these will be compared to students that use Hegartymaths. In the case of researching which topics and types of questions are best suited to Hegartymaths, the large data set studied was generated from all United Learning schools, where all pupils have access to Hegartymaths.

A *mathematised* world discounts attributes that clearly have a subjective element such as taste and smell. Size, shape, position and number are properties that can be measured and counted; these are the 'real' properties that make the grade scientifically (Husserl, 1970) and these will be the properties I am interested in when answering research questions 1 and 3.

> "However, the material which a scientist actually has at his disposal, his laws, his experimental results, his mathematical techniques, his epistemological prejudices, his attitude towards the absurd consequences of the theories which he accepts, is indeterminate in many ways, ambigious, *and never fully separated from the historical background*".
>
> (Feyerabend, 1993, p.51)

Scientists have questioned positivism's claims to objectivity, precision and certitude throughout the twentieth century, without completely abandoning the objectivism inherent in positivism (Crotty, 1998). The post-positivist makes claims that are far more modest than the positivist. They assign probabilities to the claims, which accept they have varying degrees of objectivity rather than absolute objectivity. They accept that it is not possible to view world realities free from the observer's influence and there are no longer claims of a privileged metaphysical or epistemological position (Crotty, 1998).

Having said this, existing statistics, which might be full of assumptions and therefore have limitations, provide a context for a new study (Gorard and Taylor, 2004) and what I intend to do with both research questions 1 and 3 is to investigate the existing statistics. There has been a call to make better use of secondary data for at least forty years (Bulmer, 1980), which many academics claim to do when constructing their literature reviews (Hakim, 1982). A lot of researchers choose to carry out their own data collection in pursuit of 'original work' but this is a common misconception as secondary data analysis does not restrict the originality of the research and there are claims that 'old' data can lead to more original research (Gorard, 2004). Examination results are in the public domain and the access I have to data provided by Hegartymaths allows me to be efficient, cost effective and original, whilst maintaining quality through large-scale official datasets that carry a certain authority; complete datasets of this type are always preferable as they do not introduce the additional bias when selecting a sample (Gorard, 2004). Population refers to the subjects included in all the cases the study is about (Smith, 2010), which in this study is the entire UK cohort of students who were examined in GCSE mathematics in the summer of 2019. To answer the question of how effective Hegartymaths is, there was no sampling, as the data analysed for the quasi-experiment was generated by the entire population.

There are severe limitations when employing experimental approaches to social science research (Gorard, 2004). However, if we are to assume the ideal experiment is one that isolates cause and effect, we can use this template to judge our more limited studies against. This will allow us to examine the limitations of our claims. An ideal experiment that could lead to safe and secure knowledge of how effective Hegartymaths is for the outcomes of pupils must control all variables other than that of both student and teacher access to Hegartymaths. The teacher and pupils must be identical in every way both in the control group (no Hegartymaths access) and the experimental group (Hegartymaths access). This is clearly not the case here. Both the control group and experimental group in the population used have countless differences, both in terms of the teachers and the pupils. The students will have different prerequisite knowledge, from different contexts, be placed in sets according to ability or attainment or it could be that they are arranged in mixed ability or attainment, have various class sizes and different amounts of curriculum time devoted to mathematics. This list is not nearly an exhaustive one, and the teachers have another one just as long, including: their various degrees of experience, subject knowledge, capacity for behaviour management and even how they set up their classrooms. Whilst accepting it will never be an ideal experiment, I have taken into account major issues linked to outcomes, such as comparing schools that have a similar intake of pupils to mitigate these differences.

"Every scientific statement must remain *tentative for ever*" (Popper, 1959, p.280). I subscribe to this train of thought so my intention is to research if Hegartymaths improves student outcomes from an objectivist point of view which thereby warrants further research, regardless of whether this is objectivist or constructivist research.

3.4.2 Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?

The different nature of the various topics and assessment objectives pupils are expected to answer in the mathematics GCSE has led me to teach these in very different ways within my classroom. For example, the way I teach solving equations is similar to the way Colin Hegarty chooses to do so online. This topic requires pupils to understand very little content to grasp a skill before they move on to practise their new skill. Careful planning of questions allows pupils to see differences between the equations, which tests their understanding and application of the skills they have previously learnt, such as eliminating terms using inverse operations, collecting like terms or expanding brackets.

After completing a series of online quizzes on equations, pupils are exposed to all the different types of equations they could be asked to solve. This indicates that they have learnt what to do in specific circumstances but this has not established that they know when to do this, which is a common misconception I encounter often that teachers of mathematics make and one that I also made. The incorrect assumption is that by answering all the questions correctly in isolation, pupils have the necessary skills to answer these questions when presented with the same questions simultaneously. Pupils might possess all the mathematical skills independently, however the skill of recognition and application are yet to be tested in this way, and this is something that Hegartymaths does not address.

This importance of recognising which topic of mathematics the question is asking varies according to the topic. Solving equations, in the example above, is far less demanding than circle geometry for example in terms of recognising what to do, and when. My experience has led me to believe that the key to success in circle geometry is plenty of practice in recognising shapes before putting pencil to paper and solving the problem. This very different nature of the topics of mathematics suggests that the outcomes of using Hegartymaths will vary depending on the topic.

Similarly, depending on what the assessment objectives the exam board wishes to test are, each question will have various levels of outcomes. Hegartymaths and online video tutorials should be suited more to AO1 questions, where fluency is the key to success. The online tutorials and quizzes do not focus as much on AO3 questions, where topics are regularly mixed in a single question and where the required problem-solving skills are more to do with reading and extracting information from the question before attempting to devise a mathematical strategy for the solution.

To investigate if there is any truth to this, I have coded the questions tested in the mathematics GSCE summer 2019 examinations. All the questions in both the higher and foundation examinations from the three major exam boards AQA, Pearson Edexcel and OCR have the relevant assessment objectives attached to them, which are published in the mark schemes and examiner's report. As for the topics, I started coding these according to the relevant Hegartymaths clip, using my own experience. I then cross-referenced a paper I coded with Pinpoint Learning, another online platform that allows you to individually target pupil weaknesses after uploading their scores on previous past papers. As well as generating their own questions according to a student's weaknesses, they too are linked with Hegartymaths and direct pupils to specific clips, where they can watch the online video tutorials and address any gaps. The cross referencing for AQA foundation paper 1 gave me confidence that Pinpoint Learning identified the same Hegartymaths clips as I did. To save time and avoid bias, I therefore have used their allocation of clips for all GCSE papers.

The Hegartymaths data I have access to are from United Learning schools. This large dataset is effectively a 'snapshot' – capturing a 'moment' of continuously-changing data - and a subset of data of the entire analytics Hegartymaths can provide, which can be described as 'big data'. This term was introduced in the mid-1990s to describe large, complex and dynamic collections of data, which exceeded the processing capacity of database architectures organisations had at the time (Weiss and Indurkhya, 1998). Big data is comprised of the 3 Vs: high volume, high-velocity and high-variety data (Gewirtz, 2018), making this type of data hard to handle as well as difficult to analyse and assimilate (Diebold, 2012). Analytics are most popularly categorised as descriptive, predictive and prescriptive (Davenport and Dyche, 2013), and this study concentrates on managing and analysing descriptive data, before reporting this data and attempting to find trends. There have been calls for more rigorous research at ground level so as to operationalise the existing and contemporary frameworks (Ruthven, 2014), and to use qualitative and quantitative data analyses simultaneously to harness the techniques of learning analytics and big data further (Hoyles and Noss, 2016). My research design offers a possible way of how this big data can be managed, by aggregating the data in the way I describe in section 4.2.4, and my interpretations described in section 6.2 that are the result of both quantitative and qualitative data from the ground level, are the ways this study attempts to contribute to the existing literature from a methodological point of view. Again, I am trying to establish links from a post-positivist lens that will enable future research to be contextualised before looking to uncover further truths, be it from an objectivist or constructivist epistemological starting point.

3.4.3 How is Hegartymaths used in the most successful schools?

Triangulation is a key reason for adopting a mixed methods approach in research. I've attempted to explore the richness and complexity of human behaviour (Cohen et al., 2011) by studying it from more than one standpoint. Hegartymaths can be used by pupils individually and can also be researched without analysing the teacher input. I agree that no single method is ever adequate in solving problems where there are rival causal factors (Denzin, 1978) and have concluded it is wise to explore the way in which teachers use Hegartymaths.

A limitation of solely using the secondary data in research question 1 is that this type of research from afar might lead to isolation of the subject of study. Choosing not to access the field, so to speak, might lead to a lack of practical realism in the research findings (Gorard, 2004). Collection of primary data might counteract this risk but this would take far too long to generate results for the entire population and a sample size of pupils within a single school is not in line with the rest of the research design. A sample is a selected subset of the population (Robson, 2011), which usually requires a decision in terms of both sampling strategy and procedure: what type of sample is needed and what approach should be adopted in selecting the individuals. For the case of the quasi experiment this was not needed as a sample was not taken. In terms of the teacher survey, the sample used data generated from United Learning schools. This decision was based on ease of access and for ethical reasons, no individual students' data is looked at. Instead, the individuals together make up the data per school, which is then compared.

The role of the teacher is essential in the outcomes of pupils, with or without Hegartymaths access. Even in the ideal experiment described earlier, where the teacher is exactly the same in the control group and the experimental group, issues arise. The experience the teacher has in using Hegartymaths is surely a factor. Knowing the questions in the quizzes will allow better selection of topics that are suited to Hegartymaths. Experience can lead to finding more successful approaches to raising the profile of Hegartymaths that in turn will motivate pupils to use it more. I have seen myself develop over the last four years, trying various ways of using the platform within the same class, as well as for different classes. Conversations with other teachers in other schools have also led me to believe that there are multiple ways of using Hegartymaths and I therefore designed a survey to gather this data from teachers in order to see whether there are patterns in the ways more successful schools use the online video tutorials.

Using surveys is often hard to justify in research (Gillham, 2000) and they are thought to be inferior as a design, compared to the better-theorised experiments (Gorard, 2004) so I have tried to rationalise my train of thought. My personal experience as a maths teacher using Hegartymaths for four years, as well as the countless discussions I have had with teachers concerning various ways Hegartymaths can be used, has given me many insights. Although acquiring this knowledge and using it for the survey can be thought of as part of the interpretivist's paradigm, the purpose of the study here is to gather relatively simple facts which surveys are known to be good for, such as the respondent's highest qualification that can be used in connection with research question 1, (Gorard, 2004).

There are more complicated questions I would like answers to, such as if teachers use Hegartymaths to 'flip' the learning and if so, how they might do this. This would be firmly in the constructivist realm and possibly a research study for a future date. The respondent may not even know what the term 'flipped learning' entails and so the data generated from this type of question through a survey would not be reliable. Realising the issues this type of question raises, I re-wrote the survey questions several times to ensure that the survey only gathers relatively simple facts.

The qualitative data generated from this could imply that I am researching the online platform from a constructivist point of view, which I accept. After all, Hegartymaths does allow the learner to have a lot of control over their own learning and they are given the opportunity to negotiate content, assignments, procedures and deadlines to varying degrees and according to how the teacher or school want their pupils to use this. The way a school or teacher intends for their students to use Hegartymaths results in different ways teachers provide support for learners to manage their own learning and assigned tasks, a key feature of a constructivist course (Vrasidas, 2000). Here, key ingredients pertaining to the success of Hegartymaths can include: intelligence, background knowledge and motivation, which are variables impossible to control (Cziko, 1989). Although I accept it is impossible to ascertain the extent of how relevant any of these uncontrolled variables are through this piece of research, I hope to uncover findings that can be used to contextualise further research on the matter.

3.5 Data protection and ethical approval

The Vienna Circle that coined the paradigm 'logical positivism', linked truth to meaning in such a way that does not allow any pathway, other than science, to genuine knowledge. This led to the exclusion of metaphysics, theology and ethics from the domain of warrantable human knowledge (Crotty, 1998). This alone was enough for me to discount logical positivism and the post-positivist paradigm is much more suited to social science research and in particular education, where ethical considerations are of utmost importance.

Ethical considerations meant that all data collected and stored were in accordance with the Data Protection Act 1998. Personal data, including both student identification numbers and teacher names for the survey were not requested. Survey results, GCSE results and Hegartymaths data were analysed by school, where comparisons could be made without identifying specific teachers or students.

Participation in the survey was voluntary and teachers had the right not to partake in the research. Anonymity and confidentiality were both ensured and the online survey included information explaining the purpose of the study as well as how the data would be used. To avoid bias, the purpose of the survey was given after Hegartymaths was used and the GCSE examinations had taken place. Covert research was used in this instance, where the researcher does not disclose that research is being conducted to the participants (Spicker, 2011) and the main reason for this is to avoid behavioural changes that may invalidate the research (Robson, 2011; Spicker, 2011).

Another important ethical consideration when designing the quasi-experiment is that the intervention of Hegartymaths or level of this 'treatment' was decided by the school and the learners' teachers. In order to try and mirror a positivist scientific experiment, I would have to control as many variables as possible and randomly assign pupils to be educated with or without Hegartymaths. As I do value the opportunities this platform provides learners, it would not be ethical to disadvantage some pupils from access to Hegartymaths.

3.6 Validity and reliability of the research

There have been claims that there is no longer the need to talk of objectivity, or validity, or generalisability and that quantitative research has valuable contributions to make without these claims (Crotty, 1998). However, they do become more important in research projects that deal with large datasets, similar to this project, especially if this is to provide context for further research into Hegartymaths.

Validity and reliability of research must be considered regardless of the methodological approach used. Threats to both validity and reliability can arise at any phase of the research process: sampling procedures, data collection, instruments and measures used are just a few examples. Critical thought must be given to the research method to ensure the quality and integrity of the data (Smith, 2010).

Traditional quantitative criteria – internal validity, reliability and generalisability – are used to inform the rigour of research (Smith, 2010). Internal validity is described as "the extent to which the findings of a study are a true reflection of phenomena under study" (Smith, 2010, pg. 57). This means the research findings must accurately represent the phenomena being studied (Cohen et al., 2011). Generalisability, otherwise known as external validity, questions how applicable it should be to extend the research findings to a wider population (Cohen et al., 2011, Smith, 2010). Reliability is concerned with how reproducible or internally consistent the procedures, measures and data are (Smith, 2010). These terms are all used and discussed with respect to my study in section 6.

Chapter 4: Research Design

4.1 Introduction

In this section I describe how I have gathered and arranged the vast amounts of data in the study in an attempt to answer my research questions. I have separated these into two sections; the first of which explains this process for the data needed for my first two research questions:

- *To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE?*
- *Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?*

The data gathered that was required to answer these questions was comprised of common raw data files as well as certain key measures, which are described together. I explain the rationale I used to clean this data before analysing it, before I turn my attention to describing both the process needed, and rationale for, the acquisition of the survey results in attempting to answer my third research question:

- *How is Hegartymaths used in the most successful schools?*

All data needed to answer my research questions used common statistical tests to analyse and interpret the data, which is described in the last section of my research design.

4.2 Data gathered for research questions 1 and 2

The quantitative data gathered for this study comes from various sources. The vast amounts of secondary data collected were reduced in all cases and then combined in some cases, before analysing, to answer the following research questions:

- *To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE?*
- *Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?*

In this section I describe how I have arranged the data from its sources and justify the reasons for each.

4.2.1 Gov.uk website

The gov.uk website published the revised summer 2019 KS4 data for all schools in England in February 2020. This data is a public document; there is a large amount of data broken down by each school (see Appendix B for the full list provided). I reduced this data by deleting most of the columns. The columns I decided to keep as well as the rationale are described below, arranged by column number:

1 Record type (1=mainstream school; 2=special school; 4=local authority; 5=National (all schools); 7=National (maintained schools))

To ensure the comparisons made are all mainstream secondary schools in England, I deleted all rows that were not mainstream secondary schools using the data in column 1.

4 School Unique Reference Number

I used column 4 to code school names for easier analysis on excel.

5 School name

6 School now known as (used if the school has converted to an academy on or after 12 Sept 2018)

Columns 5 and 6 were used to cross reference Hegartymaths data according to school.

15 School type (see separate list of abbreviations used in the tables)

There are many school types, that are arranged into the following categories:

AC	Academy Sponsor Led
CY	Community School
VA	Voluntary Aided School
VC	Voluntary Controlled School
FD	Foundation School
CTC	City Technology College
CYS	*Community Special School*
FDS	*Foundation Special School*
NMSS	*Non-maintained Special School*
	Independent School approved to take pupils with Special Educational Needs
IND	*Independent School*
FESI	*Further Education Sector Institution*
CHS	*Community Hospital School*
FHS	*Foundation Hospital School*
PRU	*Pupil Referral Unit*
consortia: NULL used	*6th Form Centre/Consortium*
MODFC	*Institution funded by other Government department*
	Playing for Success Centres
INDSPEC	*Other Independent Special School*
ACS	*Academy Special*
ACC	Academy Converter
F	Free School – Mainstream
FS	*Special Free Schools*
ACCS	*Converter special academies*

FAP	*Free School AP*
FUTC	*Free School UTC (University Technical College)*
FSS	*Free School – Studio School*
F1619	*Free School - 16-19*
	International School
ACCAP	*Academy - Converter Alternative Provision (AP)*
ACAP	*Academy - Sponsor led Alternative Provision (AP)*
ACC1619	*Academy 16-19 Converter*
AC1619	*Academy 16-19 Sponsor Led*
AP	*Alternative Provision*
	Legacy types/Miscellaneous
	Secure Unit

The school types underlined and in italics above were identified as ones that could potentially skew the data and were removed from the national dataset. These schools fit into the following larger categories and the rationale that they have potential to skew the data is given for each of these:

'Special' schools: These schools (CYS, FDS, NMSS, CHS, FHS, ACS, FS and ACCS) have a significantly large amount of pupils with special educational needs and would make unfair comparisons. Pupils with special educational needs are counted in the mainstream secondary school comparisons when these schools include them. However, pupils with special educational needs that are in a 'special' school tend not to perform on a par with mainstream secondary schools.

Independent schools: Pupils that attend independent schools (IND, MODFC and INDSPEC) have economic and social advantages (Coleman, 2000) and receive approximately three times the amount of resources per pupil compared to non-independent schools (Henderson et al., 2020). As such, there is a substantial average advantage for private school students when assessing performance (Malacova, 2007), that amounts to nearly two thirds of a grade at GCSE level, even when controls for prior achievement were accounted for (Ndaji, Little and Coe, 2016). These schools also predominantly pick iGCSE, which is a significant departure from the conventional GCSE. For these reasons, these schools were removed from the study as they could skew the results.

Post 16 schools: Pupils in these schools (FESI, NULL, F1619, ACC1619 and AC1619) who are included in the data will be re-taking the GCSE which - in general - means they have had more time receiving education in mathematics, that I suggest could lead to unfair comparisons.

Alternative provisions: Pupils in pupil referral units or other types of alternative provision (PRU, FAP, FUTC, FSS, ACCAP, ACAP and AP) have – in the main - significantly different experiences of education. It has been said that schools offering alternative provisions do not prioritise improving attainment for their pupils and very few children make progress (Taylor, 2011). For these reasons, these schools were removed from the study as they could skew the results.

As well as the schools above, the new institutions, labelled 'NEW' in the filter, were removed as these schools did not have data that could be analysed.

25 Number of pupils on roll (all ages)

28 Number of pupils at the end of key stage 4

Number of pupils on roll using column 25 and 28 allowed me to see the overall picture; how many pupils use Hegartymaths vs non-users.

35 Percentage of pupils at the end of key stage 4 with low prior attainment at the end of key stage 2

37 Percentage of pupils at the end of key stage 4 with middle prior attainment at the end of key stage 2

39 Percentage of pupils at the end of key stage 4 with high prior attainment at the end of key stage 2

This breakdown is important to see if the effectiveness of Hegartymaths differs according to the varying degrees of prior knowledge in schools. The countable student numbers in each category were also used to assess the extent to which the control and treatment groups were comparable using a chi-square test.

41 Percentage of pupils at the end of key stage 4 who are disadvantaged

43 Percentage of pupils at the end of key stage 4 who are not disadvantaged

The breakdown provided by columns 41 and 43 is important to see if the efficacy of Hegartymaths differs according to the number of disadvantaged pupils that schools have. More details on how pupils are judged to be disadvantaged are found below (columns 192 and 208). Again, the countable student numbers in each category were also used to assess the extent to which the control and treatment groups were comparable using a chi-square test.

63 Average Attainment 8 score per pupil for mathematics element

This column provides the performance measure un-related to KS2 prior data for mathematics only. Essentially, each pupil is awarded a grade from 0 to 9 for mathematics before the mean average is calculated. For further details, see https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/561021/Progress_8_and_Attainment_8_how_measures_are_calculated.pdf

74 Number of pupils included in Progress 8 measure

The number of pupils used in the Progress 8 measure enabled me to see how different this is to number of pupils on roll. This was also used to calculate the weighted averages correctly amongst the control and treatment groups.

77 Progress 8 measure after adjustment for extreme scores

Progress 8 measures are the best indicator for highlighting highest performing schools overall. This takes prior data into account and therefore is related to the teaching and learning of the school and its pupils, regardless of their starting point. As such, the Progress 8 measure is a better indicator than Attainment 8 for the purposes of this study to measure the extent to which Hegartymaths is attributed to GCSE performance.

The full explanation of how Progress 8 is measured can be found on the Department for Education document (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/561021/Progress_8_and_Attainment_8_how_measures_are_calculated.pdf), but here is a short summary:

Pupils are assessed on their English and mathematics at the end of Key Stage 2 (~11 years old) and arranged into groups of pupils across the country that achieved the same score. When these pupils are assessed at Key Stage 4, the median average of this group is set as the Progress 8 score of 0. Pupils who achieved above the median of their score receive a positive Progress 8 score and those who achieved below the median of their group achieved a negative Progress 8 score. The calculation is done in a way that can be interpreted easily as each integer represents a grade, for example a pupil who achieved a Progress 8 measure of +1 is seen to have achieved a whole grade on average more than the median average of their Key Stage 2 group in all of their subjects. Similarly, a pupil who achieved a Progress 8 measure in the mathematics element of -0.5 is seen to have achieved half a grade less than the median average of their Key Stage 2 group in mathematics.

Although Progress 8 is a better indicator of the teaching of the school than Attainment 8, as with any measure it isn't perfect and it has been argued that Contextual Value Added (CVA), that used to be measured in the past, is a fairer assessment of the teaching that happens in schools (Leckie and Goldstein, 2017; Gill, 2018). This will be examined further in the discussion chapter.

Column 77 was also used to filter out schools that had either one of two codes here instead of a measure. The codes were:

LOWCOV	Low coverage: shown for the 'value added' measure and coverage indicator where schools have less than 50% of pupils included in calculation of the measure.
SUPP	Suppressed: In certain circumstances, GOV.UK will suppress an establishment's data. This is usually when there are 5 or fewer pupils or students covered by the measure (10 in the case of destination measures).

The ninety-six schools that fit into the categories above or had 'blanks' here were removed from the dataset as they could not be used for analysis.

For the rest of columns below, where there were several codes, these were removed which created blanks in the spreadsheet. This allowed for excel to generate calculations without these blanks being part of the averages calculated. The codes replaced for blanks were as follows:

LOWCOV	Low coverage: shown for the 'value added' measure and coverage indicator where schools have less than 50% of pupils included in calculation of the measure.
SUPP	Suppressed: In certain circumstances, GOV.UK will suppress an establishment's data. This is usually when there are 5 or fewer pupils or students covered by the measure (10 in the case of destination measures).
NE	No entries: the school or college did not enter any pupils or students for the qualifications covered by the measure.
NA	Not applicable: figures are either not available for the year in question, or the data field is not applicable to this school or college.
NP	Not published: for example, GOV.UK do not publish Progress 8 data for independent schools and independent special schools, or breakdowns by disadvantaged and other pupils for independent schools, independent special schools and non-maintained special schools. These schools were removed from the data set for other reasons (see above).
RE	Redacted: not a reliable estimate and therefore does not provide a fair measure of performance. For transparency, GOV.UK publishes the headline information for these providers separately in the national achievement rates tables.

In addition to the codes already listed, the code SP was replaced by 0.25% for a fair compromise.

SP	Small percentage: the number is between 0% and 0.5%

86 Progress 8 measure for mathematics element

Progress 8 measure for mathematics only is the best indicator we have currently for highlighting the highest performing mathematics departments. This is because it takes prior data into account and therefore is related to the teaching and learning of the mathematics department and its pupils, regardless of their starting point. The difference between this and the progress measure of the school (77) is further indication of the quality of the mathematics department in relation to the school.

192 Progress 8 measure for maths element - disadvantaged pupils

208 Progress 8 measure for maths element - non-disadvantaged pupils

These measures allowed me to see if the effectiveness of Hegartymaths differs between disadvantaged pupils and non-disadvantaged pupils.

The Department for Education (https://www.gov.uk/government/publications/pupil-premium-conditions-of-grant-2018-to-2019/pupil-premium-2018-to-2019-conditions-of-grant) identifies disadvantaged pupils as:

- Eligible for Free School Meals or have been in the last six years;
- Looked After Children (LAC), or those who have previously been looked after by the state, but are now adopted or are subject to a special guardianship order, a child arrangements order or a residence order;
- Children with parents in the armed forces.

Children that are disadvantaged in comparison to others because of their socio-economic status, or with little or no family support (LAC), or who have lots of school moves have been proven to have a negative impact on progress and attainment when compared to others in the UK (Machin, McNally, and Wyness, 2013) and hence an important factor to consider is the level of disadvantaged pupils within the control and treatment groups.

228 Adjusted Progress 8 measure - pupils with low prior attainments

237 Adjusted Progress 8 measure - pupils with middle prior attainment

246 Adjusted Progress 8 measure - pupils with high prior attainment

These measures permitted me to see if the efficacy of Hegartymaths differed between pupils who have low/middle/high prior attainment.

The Department for Education (2019) identifies these groups according to KS2 data as:

Low:	Average score for reading and mathematics below Level 4
Middle:	Average score for reading and mathematics below Level 5 but greater or equal to Level 4
High:	Average score for reading and mathematics greater than or equal to Level 5

Reducing the initial data set using the criteria detailed above, the schools left within the sample had 3,181,755 pupils on roll, as opposed to the 3,366,207 originally in the data set. This represents 94.5% of the entire population of pupils in secondary education within the UK.

4.2.2 Hegartymaths and Pinpoint Learning

Both Hegartymaths and Pinpoint Learning websites were used to identify the Hegartymaths clips associated with each of the questions in the 2019 GCSE papers for AQA and Edexcel. Both teams responsible for the websites have a team dedicated to analysing and subsequently sorting the information gleaned from the videos, so that they are matched to the GCSE papers' questions. I used these two websites to cross-reference whether both were selecting the same clips. Where both websites did not agree, I left these out to avoid bias towards one website.

4.2.3 Examination boards

AQA and Edexcel produce exam reports that show the average marks gained for each part of the question by the entire cohort for each school. I have access to these reports for all 37 United Learning schools. The Edexcel reports are organised such that each school has a different order of questions in the report, some of which have the same description across the papers, regardless of tier. This forced me to recode every question so that I could organise them in such a way where I could compare the performance of each school according to each question.

A further complication that came to light is the comparison in performance of questions that are of the same topic but from different exam boards, e.g. 'solving equations' could be on Q3 on AQA Foundation Paper 1 (non-calculator) and also on Q5 of the Edexcel Higher Paper 2 (calculator). Even if they were categorised by the same assessment objective, e.g. AO1, the questions could be different enough to suggest one is more difficult than the other. Even if it were somehow possible to determine if these questions were of equal difficulty, the fact that 'higher' pupils would be compared to 'foundation' pupils would result in an unfair test. This led to my having to make the decision to look at each board separately in the question-by-question analysis.

To observe if Hegartymaths is more successful in GCSE performance on particular papers, namely calculator or non-calculator, tier of entry (foundation or higher) and specific areas of mathematics tested (number, algebra, geometry, ratio, probability or statistics), the descriptive data was gathered from both exam boards' secure websites (which is accessed freely for schools who use these boards for the GCSE examinations), and then amalgamated before patterns were observed. This decision was made in order to look across both exam boards, who code each question in the same way.

This was also the case for analysing if Hegartymaths was more successful for certain assessment objectives (AO1, AO2 or AO3). Each exam board codes each question asked according to the guidelines set by the Department for Education:

"AO1 Use and apply standard techniques

Students should be able to:

- accurately recall facts, terminology and definitions;
- use and interpret notation correctly;
- accurately carry out routine procedures or set tasks requiring multi-step solutions.

AO2 Reason, interpret and communicate mathematically

Students should be able to:

- make deductions, inferences and draw conclusions from mathematical information;
- construct chains of reasoning to achieve a given result;
- interpret and communicate information accurately;
- present arguments and proofs;
- assess the validity of an argument and critically evaluate a given way of presenting information.

Where problems require students to 'use and apply standard techniques' or to independently 'solve problems', a proportion of those marks should be attributed to the corresponding Assessment Objective.

AO3 Solve problems within mathematics and in other contexts

Students should be able to:

- translate problems in mathematical or non-mathematical contexts into a process or a series of mathematical processes;
- make and use connections between different parts of mathematics;
- interpret results in the context of the given problem;
- evaluate methods used and results obtained;

- evaluate solutions to identify how they may have been affected by assumptions made.

> Where problems require students to 'use and apply standard techniques' or to 'reason, interpret and communicate mathematically', a proportion of those marks should be attributed to the corresponding Assessment Objective."
>
> (Edexcel, 2015).

The data was arranged so that each subset of each question in the summer 2019 series had attached the question number, description, maximum marks, assessment objective, area of mathematics tested for and associated Hegartymaths clips. There were some questions without Hegartymaths clips attached and others that had multiple Hegartymaths clips associated with them, up to a maximum of four. In these instances, I decided that all of the time spent by students on all of these clips be counted as they all potentially contributed to the marks gained in the GCSE, but if these questions proved to be statistically significant, it was conceded that there was no plausible method that enabled me to pinpoint exactly which of the Hegartymaths videos or quizzes the statistics were attributed to.

4.2.4 United Learning annual Hegartymaths skills information

Without access to the analytics provided by Hegartymaths and United Learning, this project would simply not exist. Before describing what the data contains, I give a brief summary of the steps I took to be granted access to the data itself, and how I established a level of trust with Hegartymaths and United Learning such that I was able to conduct the research without further intervention from either organisation.

In 2016, I joined a mixed secondary school that is part of United Learning, as Assistant Principal in charge of Teaching and Learning. In 2016, Hegartymaths was brought into all United Learning schools, after subscriptions for all pupils had been purchased by the MAT, and I started using the software with my own classes for the first time. I was also line managing the mathematics department and was heavily involved in the implementation and embedding of Hegartymaths from the outset. This included whole school and year group assemblies, where we were fortunate enough to host Colin Hegarty (co-founder of Hegartymaths) for an inspirational assembly and to provide some training to the mathematics department around how he envisaged the online platform would best be used at the ground level. At this time, I established a productive and positive working relationship with Colin Hegarty.

Further, my position as a school leader enabled me to attend various networking events, where I was able to develop relationships with other prominent figures who worked for or with United Learning, including Fay Sheppard (director of mathematics across United Learning schools), Michael Davidson (head of research and analysis), and Colin Hegarty. It was at one of these events where I described to Colin what I would like to do with my research. I explained that the research had potential to highlight which of the videos were more or less successful, through internal analysis of pupils who use Hegartymaths, by analysing their use of the online platform in line with their examination results. I was hopeful that this could lead to the creation of other videos that could teach the concept through different and more successful methods, before giving an example of the way I teach proportional reasoning through a unique method I had developed. Colin was instantly interested and endorsed my project; I was able to confirm in writing reasonably quickly that I would be granted the rights to use the Hegartymaths data for my research. Colin also requested that the Hegartymaths data team collaborate with me (see section 4.2.5) to provide data from UL schools across the UK. Throughout the project, I regularly emailed the Hegartymaths data team for assistance and to provide snapshots of my research, which they periodically requested access to, without intervention.

I also had some meetings with United Learning, who were interested in being part of the research as this could potentially help steer their manifold mathematics departments to adopt better ways to deploy Hegartymaths. Following these meetings, I was given the Hegartymaths data I required in the raw format from Michael Davidson, and all United Learning schools' GCSE examination results breakdown question-by-question were provided by Fay Sheppard.

The 'United Learning annual Hegartymaths skills information' is a spreadsheet that contains Hegartymaths data for each of the 30,501 pupils in 37 United Learning schools, which represent 1.19% of mainstream secondary schools in England, that encompass 1.08% of the total pupils on roll in the country; further, UL accounts for 1.02% of the total pupils in KS4 and 0.99% of the pupils used to calculate the national Progress 8 measures.

The Hegartymaths team compiled a Excel spreadsheet for the academic year 2018-19, which contains the following information for each pupil (anonymised) in the dataset:

- School name
- Year group
- Hegartymaths data broken down for each clip, in terms of:
    - Duration – the amount of time spent on answering the quiz associated with the clip, measured in seconds;
    - Attempts – the amount of attempts on that particular clip;
    - Watched – the amount of time spent on watching the clip, measured in seconds;
    - Score – the highest score achieved on the quiz of the associated clip as a percentage.

For the question-by-question analysis which contributed to my findings in relation to the question *'Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?'* I was fortunate enough to acquire the Hegartymaths data for all of the United Learning schools (UL). The spreadsheet here included Hegartymaths data for every pupil in year 7-11 of the 37 UL schools. For each pupil, the general information displayed was:

HegartyMaths UID	UPN	School name	Year group	Account created at

Table 4.1: Extract 1 from the raw data supplied by the Hegartymaths data team

As well as the previous extract, Hegartymaths data was given for each pupil on a yearly basis:

1617 Logins	1617 Correct answers	1617 Incorrect answers	1617 Correct Fix Up 5 answers	1617 Assessment time	1617 Video watch time	1617 Fix Up 5 time

Table 4.2: Extract 2 from the raw data supplied by the Hegartymaths data team

The extract above is an example of the data recorded for the academic year from September 2016 to August 2017. As not all the schools had used Hegartymaths from September 2016, I deleted this data and used only the data from September 2018 to August 2019. I considered the data of all year groups, which gave me a snapshot of what a single pupil would access on Hegartymaths throughout their secondary mathematics education (see below for justification).

As 'Fix-up 5' was a relatively new Hegartymaths addition, this was not considered in the correlations and this too was deleted. The amount of logins, as well as correct and incorrect answers were also data not considered. The time spent on the quiz (assessment time) and watching the associated video (video watch time) were deemed the most important data.

The 'Last Login' and '1819 Logins' columns were used to identify inactive accounts and these were removed from the data. There are many examples of schools that have pupils who have created an account, only to leave the school in the near future.

A new column was created using the sum of the assessment time and video watch time in order to calculate the total time spent by each specific pupil on Hegartymaths.

The selection of the year groups posed some interesting questions. Below Yr7 and above Yr11 were removed first from the dataset as this study is based on secondary GCSE performance. Analysing the performance of only Yr11 was considered, but I chose to keep all the data from Yr7-11. The assumption here is that every pupil in a school who uses Hegartymaths will expose their pupils to roughly the same amount of content in the same order according to the scheme of work, which has been designed by United Learning and is, in the main, used by all their schools. So, even if the data accumulated by a school involves more than Yr11, the data snapshot assumes that the totals of Yr7-11 in one year reflects the cumulative journey all pupils make through their secondary maths education. Using aggregated data of this nature, where data from multiple pupils in multiple year groups are condensed and used to represent an average pupil in the school, is associated with many assumptions and limitations which are explored further in chapter 6. The alternative, however, would involve tracking and analysing exam results and Hegartymaths data of each of the 171,548 pupils who used Hegartymaths across England and who were examined in Summer 2019, as well as the 5,337 United Learning pupils, whose data I used in my later sample to compare United Learning schools. If permission was granted to use this data across schools and it was also feasible from an ethical point of view, both the alternatives mentioned would take considerably more time and would warrant a national study with many people working on the project; this is something I do recommend for possible future study.

The bank of clips was narrowed down to include only those that were tested in the 2019 summer examinations. Two slightly different data sets were created for each board, as the questions were different and therefore the clips associated, identified by the Hegartymaths and Pinpoint Learning websites, were also different. 'Attempts' and 'score' were data points that were eradicated as these were deemed less important for establishing a connection with how effective Hegartymaths is for GCSE performance. The time taken to watch the video and attempt the quiz provided richer data and would reflect whether a pupil had to re-attempt a quiz or re-watch a video tutorial because their score indicated a lack of understanding. I wanted to establish if there was a link between time spent on Hegartymaths and performance at GCSE, so the sum of the time taken to watch the instructional tutorials with the time needed to attempt the quiz was also used to look for correlations during the question-by-question analysis.

When examining if there was a link between time spent on any Hegartymaths clips with the school's performance, I looked for correlations between the performance figures and:

1) Overall time spent on Hegartymaths;
2) Time spent on watching the videos only;
3) Time spent on attempting the quizzes only.

This was to see if watching the video had a different effect on GCSE performance as opposed to solely completing the quiz. Teachers sometimes direct pupils to watch the video and make notes before taking the quiz online, whereas there is another common approach whereby students should only watch the instructional video if they cannot do the quiz. By separating these times into these two elements, this study will attempt to see whether the time spent on the quiz contributes more or less to the GCSE performance than the time spent on watching the video.

A further issue identified at this point is that the Hegartymaths data has no indication of whether a student has done higher or foundation tiered examinations, which would have allowed me to isolate the time spent on Hegartymaths in the light of student performance on GCSE foundation/higher papers. As such, I decided to use the entire data of the school, which gave rise to the following issues that must be taken into consideration and will be explored in the discussion chapter, following the findings:

1) Higher and foundation pupils will not spend an equal amount of time on Hegartymaths.
2) The breakdown of higher and foundation pupils within each school will vary.

Screenshot examples of the raw data files can be seen in Appendix C and Appendix D.

4.2.5 Hegartymaths data team

When considering the question *'To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE?'* I decided to look at the GCSE data for the entire population. For data security reasons, I did not have permission to find out all the schools in the UK that use Hegartymaths. I made contact with the data lead at Hegartymaths, who was able to use my reduced dataset from gov.uk (see section 4.2.1), and code schools into two different groups:

1) Schools that use Hegartymaths;
2) Schools that do not use Hegartymaths.

I designed the spreadsheet to calculate the weighted averages according to each of the school's pupils on roll at the end of Key Stage 4, the amount of students used to calculate the Progress 8 measure and all the other measures in section 4.2.1. This allowed the Hegartymaths data team to share the section of the spreadsheet of these results for my analysis without breaching GDPR issues (see Appendix E). For a more detailed description of ethical consideration please see section 3.5.

4.3 Survey data

For this study to provide some insight into my third research question '*How is Hegartymaths used in the most successful schools?'* I needed to create a survey to understand how Hegartymaths is used in the United Learning Schools. This was passed through the ethical approval process (see Appendix F and Appendix G) at Canterbury Christ Church University and then created online using Microsoft Forms, which can be found in Appendix H and online here: https://forms.office.com/Pages/DesignPage.aspx?fragment=FormId%3DqmjQpA4JVU-pULG5XOocazxhWMt6hrRLrM6728VYFhJUNlZVUEpRQVhQM1o5QkFaMDFTVzhXVUtSSi4u%26Token%3D6c25ca146bdf42de887c81cdb1aef0ac. For a more detailed description of ethical consideration please see section 3.5.

The results can also be viewed on the link above as well as Appendix I, which included 106 responses from teachers who were teaching mathematics at United Learning Schools during the summer of 2019. However, I needed to separate the data of the schools that were 'most successful' in order to compare their responses with those that were not so successful.

'Most successful' schools were defined by those who saw most success with using Hegartymaths and these schools were not necessarily the schools that obtained the highest Attainment 8 or Progress 8 figures. Instead, this was determined by the correlations observed in the question-by-question analysis for each board, where the time spent on Hegartymaths for specific clips was correlated with the amount of marks students achieved in relevant questions in the GCSE examination. This was done on a school-by-school basis and the schools that generated positive and statistically significant results, formed the group 'most successful' using Hegartymaths.

4.4 Statistical tests

In this section I describe the various statistical tests, including the rationale I chose to analyse the data and draw conclusions from.

4.4.1 Correlations

To investigate the relationship between using Hegartymaths and GCSE performance, I had to calculate many correlations. The Pearson correlation coefficient, r, and associated probability, p, were calculated using Microsoft Excel. I considered using SPSS, but it became evident that using Excel allowed me to read the data more easily and highlight significant results (under 5% chance) more efficiently (see Appendix J for an example).

4.4.2 T-tests

T-tests were used to analyse the extent to which control and treatment groups were comparable. In this study, the large data set was gathered from the gov.uk website and then arranged into two groups by the Hegartymaths data team; 1012 mainstream secondary schools in England that use Hegartymaths and 2098 mainstream secondary schools that do not use Hegartymaths (as of July 2019), formed the treatment and control groups respectively. The large groups allowed for me to assume that the various test statistics that measured performance would follow a normal distribution, as this is what is used by the examination boards to assign grades to pupils. Where a t-test is referred to in the findings chapter, note that this is an independent 2-tailed test. These were conducted using Microsoft Excel (see Appendix K for an example).

4.4.3 Mann-Whitney *U* tests

When ascertaining how comparable my reduced sample of 37 United Learning schools was to the rest of the population (3073 mainstream secondary schools), the groups were not large enough to use a T-test as I could not assume the test statistics would follow a normal distribution. In these instances, I used the non-parametric equivalent for independent samples to the t-test, known as the Mann-Whitney *U* test. Microsoft Excel was not able to aid me in these calculations, so where the *U* statistic and corresponding *p* value are calculated in this study, this was done on SPSS (see Appendix L for an example). The effect size, *r*, was however calculated using Microsoft Excel (see Appendix M for an example).

4.4.4 Chi-square tests

To compare the control and treatment groups in all parts of this study where countable measures were observed, a chi-square test was performed. Actual and expected tables were created on Microsoft Excel and then the corresponding chi-square statistic, χ^2, and associated probability, *p*, were calculated using these tables. Because of the vast amounts of data used, more often than not, these results proved to be statistically significant, so the effect size phi, ϕ, was also calculated to examine how different the groups were (see Appendix N for an example).

Chapter 5: Findings

The following section describes the analysis of the data, which is amalgamated from multiple sources. It is arranged according to the research questions and within those the answers to the related sub-questions are discussed.

5.1 To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE?

The results described in this section analyse data in an attempt to shed light on the impact Hegartymaths has on student outcomes by focusing on:

- Data across the UK
- Data within United Learning schools

The data across the UK was used to analyse the similarities and differences between schools that use Hegartymaths and ones that do not use Hegartymaths. The project then focuses on the 37 United Learning schools that all have Attainment 8, Progress 8 and Hegartymaths data, to look for correlations between the time spent on Hegartymaths and various GCSE performance scores.

5.1.1 How do Hegartymaths schools perform compared to non-Hegartymaths schools?

The GOV.uk website publishes the GCSE performance of all schools every year and this is a public document. The schools used for this study were carefully selected so as to only draw comparisons within one category (see methodology chapter): mainstream, state-funded secondary schools.

The calculations needed to analyse the data were pre-populated in an Excel spreadsheet and sent to the Hegartymaths team to code which mainstream, state-funded secondary schools were Hegartymaths schools (this is defined as schools that currently have a Hegartymaths subscription). These schools were compared to non-Hegartymaths schools (the schools that do not have a Hegartymaths subscription), which can be considered the control group in a quasi-experimental design.

5.1.1.1 Are Hegartymaths schools comparable to non-Hegartymaths schools?

This section used the non-performance related measures from the GOV.uk website to ascertain the extent to which the control group (non Hegartymaths schools) is comparable to the experimental group (Hegartymaths schools). Some overall performance measures are also compared but these were not the measures specifically related to mathematics, although these overall performance measures of the school are, in part, made up of their mathematics results.

	Number of pupils on roll (all ages)	Number of pupils at the end of key stage 4	Percentage of pupils at the end of key stage 4 who are boys (%)	Percentage of pupils at the end key stage 4 who are girls (%)	Key stage 2 Average Points Score of the cohort at the end of key stage 4	Percentage of pupils at the end of key stage 4 with low prior attainment at the end of key stage 2 (%)	Percentage of pupils at the end of key stage 4 with middle prior attainment at the end of key stage 2 (%)	Percentage of pupils at the end of key stage 4 with high prior attainment at the end of key stage 2 (%)	Percentage of pupils at the end of key stage 4 who are disadvantaged (%)	Percentage of pupils at the end of key stage 4 with English as additional language (EAL) (%)	Percentage of pupils at the end of key stage 4 with special educational needs (SEN) (%)
HM schools	1056814	171548	50.38	49.62	28.566	10.30	44.52	40.54	28.10	16.95	12.51
Non-HM schools	2124941	350905	50.28	49.72	28.856	9.62	42.15	43.26	24.71	16.02	12.42

Table 5.1: Non-performance measures of Hegartymaths and non-Hegartymaths schools

There are 1012 schools of the 3110 mainstream secondary schools in England that used Hegartymaths prior to the June 2019 GCSE mathematics exam. The pupils in Hegartymaths schools in the sample represent 33.21% of mainstream secondary schools in England that encompass 31.39% of the total pupils on roll in the country; further, Hegartymaths schools account for 32.84% of the total pupils in English mainstream schools in KS4 and 31.89% of all pupils used to calculate the national Progress 8 measures in England.

	Pupils at the end of key stage 4 who are boys /girls	Pupils at the end of key stage 4 with low prior attainment at the end of key stage 2	Pupils at the end of key stage 4 with middle prior attainment at the end of key stage 2	Pupils at the end of key stage 4 with high prior attainment at the end of key stage 2	Pupils at the end of key stage 4 who are disadvantaged	Pupils at the end of key stage 4 with English as additional language (EAL)	Pupils at the end of key stage 4 with English as their first language	Pupils at the end of key stage 4 with special educational needs (SEN)
χ^2	0.484	59.484	263.137	350.645	692.065	72.102	92.588	0.798
p-value	.487	<.001	<.001	<.001	<.001	<.001	<.001	.372
ϕ-value	.0010	.011	.022	.026	.036	.012	.013	.001

Table 5.2: Chi-square tests: non-performance measures of Hegartymaths and non-Hegartymaths schools

Using chi-square tests, χ^2, to analyse differences of all the countable measures I found that the very large dataset indicated significant differences for all the categories highlighted with a p <.05. However, the phi-values, ϕ, calculated for the significant results can be interpreted as a very weak relationship, if any at all, which enables me to conclude that these groups are comparable. For the prior data comparison using the Key Stage 2 Average Points Score of the cohort at the end of Key Stage 4, an independent non-paired t-test was conducted generating the following result:

	Key stage 2 Average Points Score of the cohort at the end of key stage 4
HM schools	28.566
Non-HM schools	28.856
HM – non-HM	-0.2902
Pooled SD	1.4557
Standard error	0.0557
t-statistic	5.2097
DF	3108
p	<.001

Table 5.3: T-test: prior data of Hegartymaths and non-Hegartymaths schools

Hegartymaths schools inherit a significantly slightly weaker cohort of pupils in comparison with schools that do not use Hegartymaths; the 0.29 difference in Key Stage 2 Average Point Score indicates 0.048 of a Key Stage 2 level difference.

5.1.1.2 How do Hegartymaths schools compare to non-Hegartymaths schools according to GCSE performance measures?

The performance measures used in this section are the Attainment 8 and Progress 8 scores for the schools' results. The first part of this section considers the performance measure of the schools as a whole, which considers multiple subjects, before the second part of the analysis turns solely to school performance in mathematics. The Attainment 8 and Progress 8 scores are further broken down into the various groupings of pupils that make up the context of the schools. The test conducted to look for significance of performance variation was an independent non-paired t-test.

5.1.1.2.1 How do Hegartymaths schools compare to non-Hegartymaths schools according to whole school GCSE performance measures?

	Average Attainment 8 score per pupil	Progress 8 measure after adjustment for extreme scores	Average Attainment 8 score per disadvantaged pupil	Adjusted Progress 8 measure - disadvantaged pupils	Adjusted Progress 8 measure - non-disadvantaged pupils	Average Attainment 8 score per pupil with low prior attainment	Adjusted Progress 8 measure - pupils with low prior attainments	Average Attainment 8 score per pupil with middle prior attainment	Adjusted Progress 8 measure - pupils with middle prior attainment	Average Attainment 8 score per pupil with high prior attainment	Adjusted Progress 8 measure - pupils with high prior attainment
HM schools	46.96	0.00	38.46	-0.35	0.14	24.18	0.01	40.25	0.01	60.18	-0.01
Non-HM schools	48.30	0.03	38.29	-0.38	0.15	24.03	0.00	40.33	0.01	61.40	0.05
HM – non-HM	-1.34	-0.02	0.17	0.04	-0.01	0.15	0.01	-0.08	0.00	-1.23	-0.06
Pooled SD	8.81	0.46	10.05	0.52	0.43	8.99	0.45	8.79	0.49	7.60	0.51
Standard error	0.34	0.02	0.38	0.02	0.01	0.34	0.02	0.34	0.019	0.29	0.02
t-statistic	3.98	1.31	0.43	1.83	0.88	0.43	0.62	0.23	0.18	4.21	2.92
DF	3108	3108	3108	3108	3108	3108	3108	3108	3108	3108	3108
p	<.001	.189	.667	.068	.379	.668	.536	.814	.855	<.001	0.004

Table 5.4: T-tests: Whole-school performance measures of Hegartymaths and non-Hegartymaths schools

The above results indicate that non Hegartymaths schools tend to score higher on attainment overall, specifically for the pupils with high prior attainment and a *t*-test showed that these results are statistically different, which is signified by the highlighted cells above, where $p<.05$. The non Hegartymaths schools outperform the schools using Hegartymaths in terms of progress too, although only slightly, which proved to be insignificant.

Although the two groups – schools using Hegartymaths and schools that do not use Hegartymaths – are comparable in most categories, indicated by the majority of categories yielding non-significant results in the *t*-tests conducted, the differences must be noted before analysing the results for mathematics only, especially the statistically significant results of overall attainment (t=3.9847, p<.001) and attainment of pupils with high prior attainment (t=4.2142, p<.001). This is explored further in the discussion chapter, where the impact of context is further explained.

5.1.1.2.2 How do Hegartymaths schools compare to non-Hegartymaths schools according to mathematics GCSE performance measures?

	Average Attainment 8 score per pupil for mathematics element	Progress 8 measure for mathematics element	Average Attainment 8 score per disadvantaged pupil for mathematics element	Progress 8 measure for maths element - disadvantaged pupils	Average Attainment 8 score per non-disadvantaged pupil for mathematics element	Progress 8 measure for maths element - non-disadvantaged pupils	Average Attainment 8 score per pupil for whom English is an additional language for mathematics element	Average Attainment 8 score per girl for mathematics element	Average Attainment 8 score per boy for mathematics element
HM schools	9.07	-0.01	7.32	-0.33	9.74	0.11	9.08	9.08	9.07
Non-HM schools	9.37	0.02	7.31	-0.36	9.96	0.13	9.23	9.27	9.41
HM – non-HM	-0.30	-0.03	0.01	0.03	-0.22	-0.02	-0.15	-0.19	-0.35
Pooled SD	1.81	0.44	2.00	0.49	2.01	0.42	4.82	2.61	2.86
Standard error	0.07	0.02	0.08	0.02	0.08	0.02	0.18	0.10	0.11
t-statistic	4.35	1.61	0.15	1.51	2.90	1.22	0.82	1.94	3.16
DF	3108	3108	3108	3108	3108	3108	3108	3108	3108
p	<.001	.107	.878	.132	.004	.222	.414	.053	.002

Table 5.5: T-tests: GCSE mathematics performance measures of Hegartymaths and non-Hegartymaths schools

The results in the table above indicate statistically different measures that imply non Hegartymaths schools tend to score higher on attainment of mathematics overall (t=4.3530, p<.001), specifically for the pupils that are not disadvantaged (t=2.9048, p=.004) and for boys (t=3.1559, p=.002).

The non Hegartymaths schools outperform the schools using Hegartymaths in terms of progress in mathematics too, although only slightly, which proved to be insignificant and is in line with the 0.03 difference seen in the overall school performance in terms of progress. However, when considering progress made in mathematics for the disadvantaged pupils, HM schools reversed the trend by outperforming non-HM schools in this measure. Both of these results, when looked at in isolation, were found to be insignificant according to the *t*-test conducted. It is important to note that when observed together, it can be argued that Hegartymaths schools make at least as much progress in mathematics as schools that do not use Hegartymaths, if not more than these schools for disadvantaged pupils. This is explored further in the discussion chapter, where the impact of context is further explained.

5.1.2 How do mainstream secondary United Learning schools compare with non-United Learning mainstream secondary schools?

Before analysing the Hegartymaths data for the UL schools in the sample, a comparison has been made between UL schools and non-UL schools, in order to establish the differences between the population and sample.

The data used for comparison is from the GOV.uk website, which published these results in February 2020. The comparison is made between the 3110 mainstream secondary schools (see Research Design section for extractions), that contain 3181755 pupils of the 3366207 in England (94.5%).

5.1.2.1 Non-performance measures

These measures look at various different aspects of the context of the schools, excluding performance, between KS2 and KS4.

	Number of pupils on roll (all ages)	Number of pupils at the end of key stage 4	Percentage of pupils at the end of key stage 4 who are boys (%)	Percentage of pupils at the end key stage 4 who are girls (%)	Key stage 2 Average Points Score of the cohort at the end of key stage 4	Percentage of pupils at the end of key stage 4 with low prior attainment at the end of key stage 2 (%)	Percentage of pupils at the end of key stage 4 with middle prior attainment at the end of key stage 2 (%)	Percentage of pupils at the end of key stage 4 with high prior attainment at the end of key stage 2 (%)	Percentage of pupils at the end of key stage 4 who are disadvantaged (%)	Percentage of pupils at the end of key stage 4 with English as additional language (EAL) (%)	Percentage of pupils at the end of key stage 4 with special educational needs (SEN) (%)
UL schools	34426	5337	49.99	50.01	27.989	14.02	51.76	34.23	40.16	22.79	12.59
Non-UL schools	3147329	517116	50.44	49.56	28.771	10.91	45.51	43.58	26.93	16.29	13.01

Table 5.6: Non-performance measures of United Learning and non-United Learning mainstream secondary schools

UL schools in the sample represent 1.19% of mainstream secondary schools in England that encompass 1.08% of the total pupils on roll in the country; further, UL accounts for 1.02% of the total pupils in KS4 and 0.99% of the pupils used to calculate the national Progress 8 measures.

	Pupils at the end of key stage 4 who are boys /girls	Pupils at the end of key stage 4 with low prior attainment at the end of key stage 2	Pupils at the end of key stage 4 with middle prior attainment at the end of key stage 2	Pupils at the end of key stage 4 with high prior attainment at the end of key stage 2	Pupils at the end of key stage 4 who are disadvantaged	Pupils at the end of key stage 4 with English as additional language (EAL)	Pupils at the end of key stage 4 with English as their first language	Pupils at the end of key stage 4 with special educational needs (SEN)
χ^2	0.034	38.123	38.720	203.340	542.452	237.118	232.412	0.004
p-value	.854	<.001	<.001	<.001	<.001	<.001	<.001	.948
ϕ-value	<.001	.009	.009	.020	.032	.021	.021	<.001

Table 5.7: Chi-square tests: non-performance measures of United Learning and non-United Learning mainstream secondary schools

Using chi-square tests, χ^2, to analyse differences of all the countable measures, I found that the very large dataset indicated significant differences for all the categories highlighted with a $p<.05$. However, the phi-values calculated, ϕ, for the significant results can be interpreted as a very weak relationship, if any at all, which enables me to conclude that these groups are comparable. For the prior data comparison using the Key Stage 2 Average Points Score of the cohort at the end of Key Stage 4, the non-parametric equivalent to an independent non-paired *t*-test was conducted: a Mann-Whitney *U* test, as the 37 UL schools were not sufficient to guarantee a normal distribution.

	Key stage 2 Average Points Score of the cohort at the end of key stage 4
UL schools	27.989
Non-UL schools	28.771
Mann-Whitney *U*	35120.5
Wilcoxon W	35823.5
z-score	-4.004
p-value	<.001
Effect size (*r*)	.072

Table 5.8 T-test: prior data of United Learning and non-United Learning mainstream secondary schools

UL schools inherit a significantly slightly weaker cohort of pupils in comparison; the 0.78 difference in Key Stage 2 Average Point Score indicates 0.13 of a Key Stage 2 level difference.

5.1.2.2 Performance measures

These measures concern the Key Stage 4 measures of the academic year 2018-19 between UL and non-UL schools. The performance measures used in this section are the Attainment 8 and Progress 8 scores for the schools' results. The first part of this section considers the performance measure of the schools as a whole, which considers multiple subjects, before the second part of the analysis turns solely to school performance of mathematics. The Attainment 8 and Progress 8 scores are further broken down into the various groupings of pupils that make up the context of the schools. The test conducted to look for significance of performance variation was an independent non-paired *t*-test.

5.1.2.2.1 How do United Learning schools compare to the rest of the mainstream secondary schools in England according to whole school GCSE performance measures?

	Average Attainment 8 score per pupil	Progress 8 measure after adjustment for extreme scores	Average Attainment 8 score per disadvantaged pupil	Adjusted Progress 8 measure - disadvantaged pupils	Adjusted Progress 8 measure - non-disadvantaged pupils	Average Attainment 8 score per pupil with low prior attainment	Adjusted Progress 8 measure - pupils with low prior attainments	Average Attainment 8 score per pupil with middle prior attainment	Adjusted Progress 8 measure - pupils with middle prior attainment	Average Attainment 8 score per pupil with high prior attainment	Adjusted Progress 8 measure - pupils with high prior attainment
UL schools	45.17	0.07	39.36	-0.19	0.21	27.17	0.31	40.29	0.03	58.57	-0.02
Non-UL schools	47.38	0.00	39.27	-0.36	0.12	24.64	0.02	40.60	0.03	59.28	-0.07
Mann-Whitney *U*	47878	50480	51550	43639	46374	38640	32671	53562	51649	53604	52300
z-score	-1.653	-1.173	-0.524	-2.021	-1.152	-2.221	-3.472	-0.008	-0.377	-0.559	-0.8
p-value	.098	.241	.600	.043	.131	.026	.001	.993	.706	.576	.423
r	0.030	.021	.009	.037	.021	.042	.066	.000	.007	.010	.014

Table 5.9 T-tests: Whole-school performance measures of United Learning and non-United Learning mainstream secondary schools

The difference of 2.21 in Average Attainment 8 scores indicates that pupils in UL schools achieve 20% of a grade less, when compared to their non-UL counterparts, in each of their 8 GCSE subjects (Maths and English (double weighted), 3 qualifications that count in the English Baccalaureate (EBacc) (these are any from the sciences, geography, history or a language), 3 further qualifications, which may or may not be EBacc subjects, or technical awards from the DfE approved list (https://www.gov.uk/government/publications/2019-performance-tables-technical-and-vocational-qualifications/2019-school-performance-tables-technical-and-applied-qualifications)).

Although these results did not prove to be significant, they are important to note when considering the gaps shown in attainment measures between UL and non-UL schools when analysing the same measure for disadvantaged pupils only, as they are considerably reduced. In fact, disadvantaged pupils at UL schools attain slightly higher than those on roll at non-UL schools and a Mann-Whitney *U* test indicated that this difference was statistically significant (U=43639, z=-2.021, p=.043). Although the effect value (r=.037) suggests only a weak difference, it is important to consider the results in context, where there is a change in the trend of attainment overall compared to attainment of the disadvantaged pupils. The same is true when considering the figures of pupils with low prior attainment for their attainment at the end of Key Stage 4 (U=38640, z=-2.221, p=.026, r=.042) and for progress (U=32671, z=-3.472, p=.001, r=.066). This is explored further in the discussion chapter, where the impact of context is further explained.

5.1.2.2.2 How do United Learning schools compare to the rest of the mainstream secondary schools in England according to mathematics GCSE performance measures?

	Average Attainment 8 score per pupil for mathematics element	Progress 8 measure for mathematics element	Average Attainment 8 score per disadvantaged pupil for mathematics element	Progress 8 measure for maths element - disadvantaged pupils	Average Attainment 8 score per non-disadvantaged pupil for mathematics element	Progress 8 measure for maths element - non-disadvantaged pupils	Average Attainment 8 score per pupil for whom English is an additional language for mathematics element	Average Attainment 8 score per girl for mathematics element	Average Attainment 8 score per boy for mathematics element
UL schools	8.82	0.12	7.58	-0.12	9.31	0.28	9.26	8.64	8.68
Non-UL schools	9.18	-0.01	7.55	-0.32	9.62	0.10	9.63	9.00	9.08
Mann-Whitney *U*	49550	48535	51734	43210	48263	44117	31314	45097	44055
z-score	-1.345	-1.532	-0.489	-2.102	-1.156	-1.941	-1.005	-1.418	-1.208
p-value	.179	.126	.625	.036	.248	.052	.315	.156	.227
r	.024	.027	.009	.038	.021	.035	.022	.026	.022

Table 5.10: T-tests: GCSE mathematics performance measures of United Learning and non-United Learning mainstream secondary schools

The 0.36 shortfall UL schools have shown in comparison to non-UL schools for the mathematics element indicates that students in UL schools perform 36% of a grade less than non-UL schools on average. However, UL schools achieve higher rates of progress than non-UL schools when considering the mathematics element. A Progress 8 rate of 0 represents the national average progress. Non-UL schools, which represent 98.9% of mainstream secondary schools and 93.5% of all schools, achieve 0.002, a figure that almost exactly represents the national average. The 0.064 difference in Progress 8 scores means that pupils in UL schools, on average, achieve 6.4% of a grade more progress in relation to non-UL schools across all of their 8 GCSE subjects used in the measure. Within the mathematics element, the progress rate of UL schools is 0.130 more than non-UL schools, meaning that pupils in UL schools on average achieve 13% of a grade more progress than non-UL schools.

Again, the Mann-Whitney *U* tests indicated that the results described above were not significant but are important to consider for contextual reasons before describing the Progress scores of disadvantaged pupils for mathematics. The national average for the progress made by disadvantaged pupils in 2019 was -0.45, and both non-UL mainstream secondary schools' as well as UL schools' disadvantaged pupils achieved higher than this: -0.363 and -0.189 respectively. The difference of 0.175 indicates that disadvantaged pupils in UL schools achieve 17.5% of a grade more progress across their 8 GCSE subjects used in the measure. Isolating the mathematics element and the progress made by disadvantaged pupils only, the difference becomes larger still: 0.208, showing that disadvantaged pupils within UL schools make 20.8% of a grade more progress in mathematics on average than non-UL schools' disadvantaged pupils and a Mann-Whitney *U* test indicated that this difference was statistically significant (U=43210, z=-2.102, p=.036, r=.038). This is explored further in the discussion chapter, where the impact of context is further explained.

5.1.2.3 Are there correlations between the time spent on Hegartymaths and performance outcomes?

Data from 37 United Learning schools was used to investigate if there is a relationship between the time spent on Hegartymaths for the year 2018-19 with the school's GCSE performance in mathematics.

The data was gathered from 30,501 pupils from the following schools:

School name	Hegartymaths accounts	Pupils on roll	% pupils on roll	Pupils who took GCSE
School 1 [1]	977	1170	84%	166
School 2 [1]	882	1010	87%	167
School 3	830	805	103%	165
School 4	383	354	108%	69
School 5	552	546	101%	93
School 6	816	781	104%	101
School 7	619	604	102%	127
School 8	838	876	96%	139
School 9 [2]	1165	1744	67%	194
School 10	799	896	89%	155
School 11	988	1069	92%	197
School 12	1010	990	102%	169
School 13 [1]	968	1056	92%	196
School 14 [1]	787	1080	73%	158
School 15 [1]	874	967	90%	156
School 16 [1]	1243	1445	86%	229
School 17	819	789	104%	147
School 18 [1]	938	1216	77%	175
School 19 [1]	680	752	90%	122
School 20	659	645	102%	84
School 21	677	652	104%	97
School 22	639	627	102%	92
School 23	791	780	101%	195
School 24 [1]	1009	1136	89%	163
School 25	749	700	107%	112
School 26 [1]	1436	1688	85%	277
School 27	897	869	103%	125
School 28 [2]	779	1769	44%	99
School 29	700	719	97%	133
School 30	558	472	118%	73
School 31	424	392	108%	100
School 32 [1]	1380	1516	91%	244
School 33	564	532	106%	103
School 34 [1]	913	1045	87%	168
School 35 [2]	825	1408	59%	148
School 36	864	835	103%	113
School 37	469	491	96%	86
TOTAL	30501	34426	89%	5337

Table 5.11: Discrepancies: number of Hegartymaths compared to pupils on roll

There are discrepancies between the amount of Hegartymaths accounts created and the amount of pupils on roll, according to the GOV.uk data. In the most extreme cases (those labelled with [2] above), these schools have pupils on roll in both primary and secondary, and also within the age range of 16 to 18; the Hegartymaths accounts counted above are only for secondary students, which explains the large differences. The schools labelled with a [1] also have discrepancies (although to a smaller degree) as they have pupils on roll aged 16 to 18, who are not accounted for in the Hegartymaths accounts figures. As for the other unlabelled schools, it may well be the case that the Hegartymaths accounts created differ from the amount of pupils on roll according to GOV.uk for the following reasons: not all pupils have been given an account; some pupils have multiple accounts; the number of pupils on roll according to GOV.uk was not accurate at the time of pulling the data due to pupils enrolling at, or leaving, the school during the academic year.

The issues these discrepancies may have posed for the data were limited by solely using the number of Hegartymaths accounts, although School 30's data does still appear to be quite irregular. Considering the smaller cohorts this school has as well as knowledge acquired by speaking to the Principal at School 30, it appears that more accounts than pupils on roll were made as quite a few students left the school mid-year. Due to ethical reasons, I could not identify these students and remove them from the data, which would have also been the case for every school that had this issue, which is more common than not. The decision was made to use the number of Hegartymaths accounts created when calculating the average time a pupil spent on Hegartymaths for all schools. As well as the overall time spent on Hegartymaths, the average time a pupil within a school spent on learning the content (video) and the average time spent on answering the related assessments (quiz) were analysed separately. The sum of these was the overall time.

Attainment and Progress were the performance outcomes that were considered in this study, and correlations for these in association with time spent were calculated.

5.1.2.3.1 Are there correlations between the time spent on Hegartymaths and attainment outcomes?

A Pearson correlation was calculated between the time spent on Hegartymaths per secondary pupil of each school on the quiz, video and overall time, with each of the various Attainment 8 measures.

		Average Attainment 8 score per pupil for mathematics element	Average Attainment 8 score per disadvantaged pupil for mathematics element	Average Attainment 8 score per non-disadvantaged pupil for mathematics element	Average Attainment 8 score per pupil with low prior attainment	Average Attainment 8 score per pupil with middle prior attainment	Average Attainment 8 score per pupil with high prior attainment
QUIZ	PEARSON *r*	.20	.47	.19	.26	.43	.29
	N	37	36	37	35	36	37
	t-statistic	1.21	3.12	1.17	1.54	2.80	1.79
	DF	35	34	35	33	34	35
	p-value	.234	.004	.249	.133	.008	.083
VIDEO	PEARSON *r*	.17	.38	.15	.35	.28	.17
	N	37	36	37	35	36	37
	t-statistic	1.00	2.39	0.93	2.14	1.68	1.05
	DF	35	34	35	33	34	35
	p-value	.326	.023	.361	.040	.103	.302
TOTAL	PEARSON *r*	.20	.47	.19	.29	.41	.27
	N	37	36	37	35	36	37
	t-statistic	1.21	3.11	1.17	1.77	2.65	1.68
	DF	35	34	35	33	34	35
	p-value	.233	.004	.252	.087	.012	.102

Table 5.12: Pearson correlations: the relationship between attainment outcomes with time spent on Hegartymaths

The results indicate no statistically significant difference was found in the overall Attainment 8 score for the mathematics element as $p = .233$. This means that attainment in mathematics is not affected by the overall time spent on Hegartymaths. The breakdown of this time into the quiz (p=.234) and video (p=.326) elements also showed that no statistically significant correlations were observed.

When isolating the disadvantaged pupils and non-disadvantaged pupils, statistically significant medium sized correlations were observed in the overall time spent, as well as the time spent for both the quiz and video elements separately for the disadvantaged pupils only.

The overall time spent on Hegartymaths indicates it is statistically significant (*p*=.012) for pupils with middle prior attainment. The medium (*r*=.41) correlation found here suggests the more time pupils with middle prior attainment spend on Hegartymaths, the higher the grade they achieve in GCSE mathematics. In particular, the time spent completing the quiz will result in a higher GCSE mathematics result for these pupils, where a medium sized (*r*=.43) statistically significant correlation (*p*=.008) was observed. The time spent on the video element of Hegartymaths showed no statistically significant correlation, where *p*=.162.

Interestingly, pupils with low prior attainment seem to benefit from learning content online through the Hegartymaths videos, where a medium sized (*r*=0.35) statistically significant correlation (*p*=.040) was observed, although these pupils did not benefit from the time they put into the quizzes or overall on Hegartymaths (*p*=.133 and p=.087 respectively).

Pupils with high prior attainment did not see any statistical benefit in their mathematics GCSE grade due to time spent overall (*p*=.102) on Hegartymaths, for either the time spent on the videos (*p*=.302) or the quizzes (*p*=.083).

5.1.2.3.2 Are there correlations between the time spent on Hegartymaths and progress outcomes?

A Pearson correlation was calculated between the time spent on Hegartymaths per secondary pupil of each school on the quiz, video and overall time with each of the various Progress 8 measures.

		Progress 8 measure for mathematics element	Progress 8 measure for maths element - disadvantaged pupils	Progress 8 measure for maths element - non-disadvantaged pupils	Adjusted Progress 8 measure - pupils with low prior attainments	Adjusted Progress 8 measure - pupils with middle prior attainment	Adjusted Progress 8 measure - pupils with high prior attainment
QUIZ	PEARSON *r*	.34	.46	.31	.20	.41	.42
	N	37	36	37	35	36	37
	t-statistic	2.13	3.03	1.92	1.14	2.64	2.70
	DF	35	34	35	33	34	35
	p-value	.040	.005	.057	.261	.012	.011
VIDEO	PEARSON *r*	.11	.22	.06	.30	.24	.25
	N	37	36	37	35	36	37
	t-statistic	0.64	1.33	0.34	1.79	1.43	1.53
	DF	35	34	35	33	34	35
	p-value	.528	.192	.706	.083	.162	.134
TOTAL	PEARSON *r*	.30	.42	.26	.23	.39	.39
	N	37	36	37	35	36	37
	t-statistic	1.83	2.72	1.58	1.36	2.45	2.53
	DF	35	34	35	33	34	35
	p-value	.076	.010	.112	.183	.019	.016

Table 5.13: Pearson correlations: the relationship between progress outcomes with time spent on Hegartymaths

The results indicate no statistically significant difference was found in the overall Progress 8 score for the mathematics element as the *p*-value=.076. This means that progress in mathematics is not affected by the overall time spent on Hegartymaths. However, the breakdown of this time into the quiz and video elements showed statistically significant results.

A medium sized positive correlation (r=.34, p=.040) was seen between the time spent completing the quiz and the mathematics progress made by that school. No statistically significant correlation was observed between the time spent on watching the video (p=.528) and the progress score for mathematics. This indicates that the time spent on answering the quiz affects the progress made on a school level for pupils in mathematics, whereas the time spent watching the videos does not contribute significantly towards progress.

Non-disadvantaged pupils did not see any statistical benefit in the progress scores for their mathematics GCSE from the time they spent overall (p=.112) on Hegartymaths, or for the time spent on the videos (p=.706) or the quizzes (p=.057). Disadvantaged pupils also did not see any statistical progress increase in mathematics due to the time spent watching the videos (p=.192) on Hegartymaths. However, disadvantaged pupils appear to make a statistical progress increase due to both the overall time they spent on Hegartymaths (r=.42, p=.010) and the time spent on completing the quizzes (r=.46, p=.005), where medium sized positive correlations were seen in both cases.

Pupils did not benefit, in terms of progress in mathematics and regardless of their prior attainment, from the time spent on watching the videos; p=.083 for low prior attainers, p=.162 for middle prior attainers and p=0.134 for high prior attainers. Low prior attaining pupils also appear not to make statistically significant progress gains by time spent overall on Hegartymaths (p=.183) or on the quizzes (p=.261). Middle and high prior attainers do make significant progress gains in mathematics due to the time spent on the quizzes (r=.41, p=.012 and r=.42, p=.011 respectively) and also depending on the time they spent on Hegartymaths overall (r=.39, p=.019 and r=.39, p=.016 respectively), where very similar positive medium sized correlations were observed.

5.2 Is Hegartymaths more useful for the outcomes of pupils on specific topics, more general areas or types of mathematical questions?

This section concerns the time pupils spent overall on the quizzes and videos for each of the specific clips on Hegartymaths, for each of the 37 UL schools. The performance of these schools on the 3 foundation and 3 higher mathematics GCSE exams for both examination boards AQA and Edexcel was analysed question-by-question. For each question, a Pearson correlation was calculated between the average time a pupil in each school spent on the associated Hegartymaths clips, with the average marks a pupil achieved on that question, for each school.

The analysis needed to be broken down by examination board and starts by focussing on the UL schools that opted for AQA (8 UL schools) before analysing the Edexcel results (29 UL schools) and finally looking at similarities and differences between each examination board.

For each board, the analysis looks at the results that were calculated question-by-question, before combining this data into different groups to look for further correlations in order to shed light on any similarities or differences observed between:

a) Schools;
b) Calculator and non-calculator papers;
c) Foundation and higher papers;

d) Questions that assess different mathematical skills according to Assessment Objective 1, Assessment Objective 2 and Assessment Objective 3 (see Research Design);

e) Questions that assess the five different areas of mathematics, as defined by the examination boards AQA and Edexcel: Number, Algebra, Geometry, Ratio, Probability and Statistics.

5.2.1 Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions for examination board AQA?

There were eight UL schools that opted for their pupils to be examined by AQA. This section of the study considered questions across all foundation and higher papers of the Summer 2019 AQA examination series in the mathematics GCSE. The questions were broken down into sub-questions in the cases where different topics were tested; there was a total of 219 different questions analysed. Correlations were calculated between the total learning time spent on Hegartymaths (a sum of time spent on the videos and quizzes) on the associated clips for these questions, with the average marks gained per pupil across each school.

Two questions across all papers did not have relevant Hegartymaths clips attached, according to both Pinpoint Learning and Hegartymaths; these were Q3 on Paper 2 of the foundation paper (reading number lines), and Q15b on Paper 2 of the foundation paper (find the x-intercept for a linear equation), which were not able to be analysed. 157 questions had 1 associated Hegartymaths clip, 50 questions had 2 associated Hegartymaths clips and 10 questions had 3 associated Hegartymaths clips. In the cases where multiple clips were associated, the total times for all clips combined were used in the correlation calculations.

Out of the 217 questions analysed, 9 questions showed statistically significant results. The full description, including the names of the associated Hegartymaths clips of these can be seen in Appendix O. They are also summarised in the table below:

Question	2Q20	3Q24	1Q14	1Q15b	1Q15c	2Q5	2Q12	3Q19	3Q22b
Tier	Foundation	Foundation	Higher	Higher	Higher	Higher	Higher	Higher	Higher
Total Marks	3	3	3	2	2	3	1	2	1
AO category	2	2	2	2	2	2	3	2	1
Topic	Geometry	Ratio	Ratio	Statistics	Statistics	Geometry	Probability	Statistics	Probability
HM clip 1	677	725	560	437	438	677	356	435	383
HM clip 2		729	332						
HM clip 3			333						
PEARSON *r*	-.852	-.797	-.714	.822	.745	.792	.729	.875	.750
N	7	7	8	8	8	8	8	8	8
t-statistic	-3.645	-2.954	-2.498	3.532	2.737	3.174	2.611	4.430	2.781
DF	5	5	6	6	6	6	6	6	6
p-value	.015	.032	.047	.012	.034	.019	.040	.004	.032

Table 5.14: Pearson correlations: significant results of the Summer 2019 AQA examination series in the mathematics GCSE question-by-question analysis

5.2.2 Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions for examination board Edexcel?

There were twenty-nine UL schools that opted for their pupils to be examined by Edexcel. This section of the study considered questions across all foundation and higher papers of the Summer 2019 Edexcel examination series in the mathematics GCSE. The questions were broken down into sub-questions in the cases where different topics were tested; there was a total of 212 different questions analysed. Correlations were calculated between the total learning time spent on Hegartymaths (a sum of time spent on the videos and quizzes) on the associated clips for these questions, with the average marks gained per pupil across each school.

Two questions across all papers did not have relevant Hegartymaths clips attached, according to both Pinpoint Learning and Hegartymaths; these were Q12a and Q12b on Paper 2 of the foundation paper: reading timetables, which were not able to be analysed. 148 questions had 1 associated Hegartymaths clip, 48 questions had 2 associated Hegartymaths clips, 12 questions had 3 associated Hegartymaths clips and 4 questions had 4 associated Hegartymaths clips. In the cases where multiple clips were associated, the total times for all clips combined were used in the correlation calculations.

Out of the 212 questions analysed, 40 questions showed statistically significant results. The full description, including the names of the associated Hegartymaths clips of these can be seen in Appendix P. They are also summarised in the table below:

Question	1Q06	1Q09b	1Q10c	1Q12bii	1Q14b	1Q16b	1Q26	1Q28	2Q08a	2Q08c
Tier	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation
Total Marks	4	2	2	1	1	1	3	4	1	2
AO category	3	1	1	2	2	1	2	3	1	1
Topic	Number	Ratio	Algebra	Geometry	Number	Algebra	Geometry	Algebra	Algebra	Algebra
HM clip 1	752	721	179	812	72	168	639	550	158	159
HM clip 2							650	554		
HM clip 3										
PEARSON	-.540	-.497	.576	.428	.558	.404	.448	.441	.405	.402
N	29	29	29	29	29	29	29	29	29	29
T STATISTIC	-3.332	-2.980	3.665	2.461	3.492	2.298	2.604	2.554	2.298	2.279
DF	27	27	27	27	27	27	27	27	27	27
p VALUE	.003	.006	.001	.021	.002	.030	.015	.017	.030	.031

Question	2Q11	2Q14	2Q16ai	2Q16aii	2Q20a	2Q20b	2Q21	2Q24	2Q27a	3Q01
Tier	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation
Total Marks	2	1	1	1	2	3	3	2	1	1
AO category	1	2	2	2	1	2	2	1	1	1
Topic	Algebra	Ratio	Number	Number	Algebra	Algebra	Algebra	Geometry	Number	Number
HM clip 1	784	331	149	149	269	272	208	509	122	17
HM clip 2			46	46		265				
HM clip 3			350	350						
PEARSON	.374	.585	.420	.442	.433	.437	.643	.590	.484	.373
N	29	29	29	29	29	29	29	29	29	29
T STATISTIC	2.096	3.745	2.403	2.562	2.493	2.525	4.362	3.799	2.878	2.087
DF	27	27	27	27	27	27	27	27	27	27
p VALUE	.046	.001	.023	.016	.019	.018	.000	.001	.008	.047

Question	3Q04	3Q05	3Q06	3Q10	3Q12	3Q18a	3Q19	3Q20	3Q25	3Q30
Tier	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation	Foundation
Total Marks	1	1	2	3	2	1	2	2	3	3
AO category	1	1	1	1	1	1	1	1	1	1
Topic	Number	Ratio	Ratio	Ratio	Ratio	Statistics	Algebra	Geometry	Ratio	Algebra
HM clip 1	102	82	87	62	330	415	281	486	94	193
HM clip 2								560		
HM clip 3										
PEARSON	.391	.403	.406	.475	.477	.387	.376	.382	.631	.495
N	29	29	29	29	29	29	29	29	29	29
T STATISTIC	2.205	2.287	2.311	2.805	2.817	2.183	2.110	2.148	4.229	2.963
DF	27	27	27	27	27	27	27	27	27	27
p VALUE	.036	.030	.029	.009	.009	.038	.044	.041	.000	.006

Question	1Q18a	1Q21b	2Q01b	2Q05	2Q10a	2Q15	2Q16	3Q15	3Q16	3Q23
Tier	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher	Higher
Total Marks	2	5	3	2	2	3	3	2	3	5
AO category	2	2	2	1	2	1	3	1	1	3
Topic	Number	Algebra	Algebra	Geometry	Probability	Algebra	Algebra	Algebra	Algebra	Geometry
HM clip 1	115	294	272	509	361	286	216	313	248	531
HM clip 2			265							
HM clip 3										
PEARSON	.498	.507	.405	.378	.414	.433	.482	.613	.559	.644
N	29	29	29	29	29	29	29	29	29	29
T STATISTIC	2.981	3.054	2.304	2.124	2.365	2.498	2.862	4.033	3.499	4.375
DF	27	27	27	27	27	27	27	27	27	27
p VALUE	.006	.005	.029	.043	.025	.019	.008	.000	.002	.000

Table 5.15: Pearson correlations: significant results of the Summer 2019 Edexcel examination series in the mathematics GCSE question-by-question analysis

5.2.3 Are there any correlations between the time spent overall on the specific Hegartymaths clips and the associated marks gained by pupils on a school by school basis?

The same data was used as in section 4.2.1.1 and 4.2.2.1 to look for further correlations. This time, instead of correlating the marks gained with time spent on Hegartymaths question-by-question, the time and marks were correlated on a school by school basis. This section concludes with a summary of the findings, which compare how correlations from the two examining bodies differ; the results from both AQA and Edexcel correlated the time spent on specific Hegartymaths topics with the marks achieved for the respective GCSE questions examined in the 2019 GCSE.

5.2.3.1 Are there any correlations between the time spent overall on the specific Hegartymaths clips and the associated marks gained by pupils on a school by school basis for the schools that chose examining board AQA?

	PEARSON *r*	N	*t*-statistic	DF	*p*-value
School 13	.217	217	3.25	215	.001
School 4	.249	217	3.77	215	<.001
School 33	.171	217	2.54	215	.012
School 3	.151	217	2.24	215	.026
School 24	.112	217	1.64	215	.102
School 23	.162	217	2.40	215	.017
School 5	.187	217	2.78	215	.006
School 14	.131	217	1.94	215	.054

Table 5.16: Pearson correlations: the relationship between the marks gained in the Summer 2019 AQA GCSE examination series in the mathematics GCSE with the time spent per pupil across each school on the associated Hegartymaths clips

Of the eight United Learning schools that chose for their pupils to be examined by AQA, 6 were statistically significant, all showing weak positive correlations. The Pearson correlation coefficients, *r*, specifically for the Hegartymaths clips that were tested in the Summer 2019 AQA examination series, show that the more time pupils spend on watching the videos and completing the quizzes on Hegartymaths, the more marks they gained in the GCSE mathematics exam for the 6 UL schools (75%). Of these schools, this is most true for the pupils of School 4 (r=0.2491, p=0.000209) and least true for the pupils of School 3 (r=0.1507, p=0.026426). School 14, who entered all pupils into the Higher tier exam, and School 24, did not return statistically significant results (p=0.053751 and p=0.101525 respectively) which indicates that regardless of the time students spend on Hegartymaths, this does not affect the marks they gain in these schools.

5.2.3.2 Are there any correlations between the time spent overall on the specific Hegartymaths clips and the associated marks gained by pupils on a school by school basis for the schools that chose examining board Edexcel?

	PEARSON *r*	N	*t*-statistic	DF	*p*-value
School 1	.144	212	2.10	210	.036
School 2	.100	212	1.45	210	.149
School 6	.160	212	2.34	210	.020
School 7	.030	212	0.43	210	.669
School 8	.091	212	1.32	210	.189
School 9	.122	212	1.78	210	.077
School 10	.056	212	0.82	210	.415
School 11	<.001	212	<.001	210	.998
School 12	.042	212	0.61	210	.543
School 15	.098	212	1.42	210	.156
School 16	.077	212	1.12	210	.263
School 17	.093	212	1.35	210	.177
School 18	.056	212	0.82	210	.415
School 19	.118	212	1.72	210	.087
School 20	.075	212	1.10	210	.274
School 21	.064	212	0.93	210	.352
School 22	.092	212	1.33	210	.184
School 25	.095	212	1.38	210	.170
School 26	.088	212	1.27	210	.204
School 27	.092	212	1.34	210	.182
School 28	.070	212	1.02	210	.311
School 29	.115	212	1.68	210	.095
School 30	.129	212	1.88	210	.061
School 31	.161	212	2.36	210	.019
School 32	.076	212	1.10	210	.272
School 34	.065	212	0.94	210	.347
School 35	.066	212	0.96	210	.341
School 36	.160	212	2.34	210	.020
School 37	.044	212	0.64	210	.520

Table 5.17: Pearson correlations: the relationship between the marks gained in the Summer 2019 AQA GCSE examination series in the mathematics GCSE with the time spent per pupil across each school on the associated Hegartymaths clips

Of the 29 United Learning schools that chose for their pupils to be examined by Edexcel, only 4 were statistically significant, all showing weak positive correlations. The Pearson correlation coefficients, *r*, above, specifically for the Hegartymaths clips that were tested in the Summer 2019 AQA examination series, show that the more time pupils spend on watching the videos and completing the quizzes on

Hegartymaths, the more marks they gained in the GCSE mathematics exam for the 4 UL schools (13.8%).

5.2.3.3 Summary: Comparison between boards

The results from section 4.2.3 indicate that more success with Hegartymaths was found with schools that chose AQA (75.0%) over Edexcel (13.8%), according to how many schools saw significantly positive statistics across all the questions of the 2019 mathematics GCSE analysed per school. However, there were more positively significant results seen within Edexcel during the question-by-question analysis in section 4.2.1.1 and 4.2.2.1, where 38 out of the 212 questions analysed (17.9%) yielded significantly positive results. In comparison, the same was true for 6 out of the 217 questions analysed (2.8%) for AQA. From this, an argument can be made that schools who want to increase performance overall by using Hegartymaths for all topics should choose AQA. This line of argument also suggests that some mathematics departments use the online platform more successfully than others. Another argument that could be made is that if a school were to use Hegartymaths for certain topics only, such as the ones highlighted in section 4.2.2.1, Edexcel would be the examining board of choice according to these findings.

5.2.4 Are there any correlations between the time spent overall on the specific Hegartymaths clips and the associated marks gained by pupils based on if the paper was a calculator or a non-calculator exam?

The same data that was used in sections 4.2.1 and 4.2.2 was grouped into calculator and non-calculator questions. Correlations were then calculated again between the marks gained for specific questions with the time spent on the Hegartymaths clips associated with these questions.

Four non-calculator papers were analysed in total; these are Paper 1s in both the higher and foundation tiers of both AQA and Edexcel. Each non-calculator paper accounts for 80 marks, which is a third of the total marks in each tier. Papers 2 and 3 are the examinations where a calculator is permitted, which account for the remaining two thirds of the marks available to every student: 160 marks.

	Non Calc Marks F	Calc Marks F	Non Calc Marks H	Calc Marks H	Total NC Marks	Total C Marks
Total marks available	160	320	160	320	320	640
PEARSON *r*	.305	.308	.133	.090	.317	.312
N	36	36	37	37	37	37
t-statistic	1.869	1.89	0.791	0.535	1.976	1.945
DF	34	34	35	35	35	35
p-value	.070	.067	.434	.596	.056	.060

Table 5.18: Pearson correlations: comparing the relationship between the marks gained and time spent on the associated Hegartymaths clips, with calculator and non-calculator examinations

No statistically significant results were observed as all *p*-values calculated were greater than .05, meaning that regardless of the time spent on Hegartymaths by pupils, marks do not either increase or decrease depending on whether the exam was a calculator or non-calculator one.

When assessing the marks allocated to calculator or non-calculator questions, of the questions yielding only positive and statistically significant results in section 4.2.1.1 and 4.2.2.1 the following was observed:

	Calculator	Non-Calculator
Total marks available across all papers and exam boards	640	320
%	67%	33%
Total marks of questions that were significant and positive	70	23
%	75%	25%

Table 5.19: Positive significant results breakdown by type of paper: calculator and non-calculator

The results above show that where positive significant correlations are seen, these are more likely to be found on the calculator paper rather than the non-calculator paper. However, a chi-square test of the countable marks did not prove to show statistical significance.

5.2.5 Are there any correlations between the time spent on the Hegartymaths clips tested in the Summer 2019 GCSE mathematics examinations with the associated outcomes of pupils according to whether they were entered for foundation or higher tiers?

Correlations were then calculated again between the marks gained for specific questions with the time spent on the Hegartymaths clips associated with these questions, using the dataset used in sections 4.2.1 and 4.2.2.

There are 6 foundation tier papers and 6 higher tier papers across both examination boards used; for both the higher and foundation tiers the maximum mark available is 240 for each tier and exam board.

	Total F	Total H
Total marks available	240	240
PEARSON *r*	.312	.109
N	36	37
t-statistic	1.912	0.646
DF	34	35
p-value	.064	.522

Table 5.20: Pearson correlations: comparing the relationship between the marks gained and time spent on the associated Hegartymaths clips, with higher and foundation tiered examinations

No statistically significant results were observed as both *p*-values calculated were greater than .05, meaning that regardless of the time spent on Hegartymaths by pupils, marks do not either increase or decrease depending on the tier the pupils took in the Summer 2019 examination series across either examination board.

Assessing only the marks of the questions yielding positive and statistically significant results in sections 4.2.1.1 and 4.2.2.1, the following breakdown of these marks in terms of foundation or higher papers was observed:

	Foundation	Higher
Total marks available across all papers and exam boards	480	480
%	50%	50%
Total marks of questions that were significant and positive	52	41
%	56%	44%

Table 5.21: Positive significant results breakdown by tier of paper: higher and foundation

The results above show that where positive significant correlations are seen in the question-by-question analysis, these are only slightly more likely to be found on the foundation papers rather than the higher tiered exams. However, a chi-square test of the countable marks did not prove to show statistical significance.

5.2.6 Are there any correlations between the time spent on the Hegartymaths clips tested in the Summer 2019 GCSE mathematics examinations with the associated outcomes of pupils according to which Assessment Objective was tested?

To answer this question, the data generated in sections 4.2.1 and 4.2.2 were placed into 3 groups, depending on the Assessment Objective the question was designed for: AO1, AO2 or AO3. Where there were discrepancies between the total marks available in each category depending on the examination board, the AQA marks were altered by multiplying each of the marks gained by the factor necessary to make them equal to the total marks available in each category of the Edexcel examination series.

Correlations were then calculated again between the marks gained for specific questions with the time spent on the Hegartymaths clips associated with these questions.

	AO1 Marks F	AO2 Marks F	AO3 Marks F	AO1 Marks H	AO2 Marks H	AO3 Marks H	AO1 Marks	AO2 Marks	AO3 Marks
Total marks available	111	57	72	100	65	75	211	122	147
PEARSON *r*	.370	.191	.246	.379	.373	.180	.412	.348	.274
N	36	36	36	37	37	37	37	37	37
t-statistic	2.319	1.133	1.481	2.423	2.381	1.085	2.675	2.198	1.683
DF	34	34	34	35	35	35	35	35	35
p-value	.027	.265	.148	.021	.023	.285	.011	.035	.101

Table 5.22: Pearson correlations: comparing the relationship between the marks gained and time spent on the associated Hegartymaths clips, with AO1, AO2 and AO3 assessment objective questions

Here positive and significant results were observed in both the AO1 and AO2 categories. Questions assessing AO1 showed a medium positive correlation (r=0.412, p=0.011) across all tiers and boards, and medium correlations in the questions assessed in both the foundation papers (r=0.370, p=0.027), and the higher tiered exams (r=0.379, p=0.023). In relation to the questions assessing AO2, these also showed a weaker but still medium positive correlation (r=0.348, p=0.035), but this was due to the AO2 questions found in the higher papers where significant results were observed (r=0.379, p=0.021), as opposed to the foundation AO2 questions where no statistical significance was observed. Questions assessing AO3 were proved to be statistically insignificant, both overall and when analysed separately according to tier of entry.

Interestingly, a similar pattern emerges when assessing the breakdown of marks allocated to AO1, AO2 or AO3 for the questions yielding only positive and statistically significant results in section 4.2.1.1 and 4.2.2.1:

	AO1	AO2	AO3
Total marks available across all papers and exam boards	358	269	333
%	37%	28%	35%
Total marks of questions that were significant and positive	52	29	12
%	56%	31%	13%

Table 5.23: Positive significant results breakdown by assessment objective questioned: AO1, AO2 and AO3

The results above show that where positive significant correlations are seen in the question-by-question analysis, these are most likely to be questions assessing AO1 than AO2, and AO2 more than AO3. A chi-square test was conducted of the countable marks and their allocation using the following tables:

Observed		AO1	AO2	AO3	
	pos.sig	52	29	12	93
	not pos.sig	306	240	321	867
		358	269	333	960

Expected		AO1	AO2	AO3	
	pos.sig	34.68	26.06	32.26	93
	not pos.sig	323.32	242.94	300.74	867
		358	269	333	960

Table 5.24: Chi-square tests: marks gained in AO1, AO2 and AO3 questions

The chi-square test of independence showed that there is a significant relationship between the marks allocated according to assessment objective (χ^2=24.0, p<.001, ϕ=0.158).

The analysis in this section concludes that there is an association between time spent on Hegartymaths topics and marks gained on the respective questions assessed in the GCSE, and that this relationship favours questions assessing AO1 over AO2, and AO2 over AO3.

5.2.7 Are there any correlations between the time spent on the Hegartymaths clips tested in the Summer 2019 GCSE mathematics examinations with the associated outcomes of pupils according to which area of mathematics was assessed?

To answer this question, the data generated in sections 4.2.1 and 4.2.2 were placed into the five areas of mathematics that both examining bodies - AQA and Edexcel - cover, which are: number, algebra, geometry, ratio, probability and statistics. Where there were discrepancies between the total marks available in each category depending on the examination board, the AQA marks were altered by multiplying each of the marks gained by the factor necessary to make them equal to the total marks available in each category of the Edexcel examination series.

Correlations were then calculated again between the marks gained for specific questions with the time spent on the Hegartymaths clips associated with these questions.

	Number	Algebra	Geometry	Ratio	Probability	Statistics
Total marks available	115	97	65	129	31	43
PEARSON *r*	.389	.394	.409	.316	-.019	.424
N	37	37	37	37	37	37
t-statistic	2.499	2.54	2.655	1.972	-0.112	2.772
DF	35	35	35	35	35	35
p-value	.017	.016	.012	.057	.911	.009

Table 5.25: Pearson correlations: comparing the relationship between the marks gained and time spent on the associated Hegartymaths clips, with the topic areas of mathematics assessed

Statistically significant and medium positive correlations were observed, in order of strength, for the questions assessing statistics (r=0.424, p=0.009), geometry (r=0.409, p=0.012), algebra (r=0.394, p=0.016) and number (r=0.389, p=0.017). Here we observe that the more time students spent on Hegartymaths within these areas, the more marks they gained in the GCSE exam on those specific questions. No statistical significance was observed for both the areas of ratio or probability.

Again, similarly to section 4.2.6, a similar pattern emerges when examining the distribution of marks allocated to the different areas of mathematics for the questions yielding only positive and statistically significant results in section 4.2.1.1 and 4.2.2.1:

	Number	Algebra	Geometry	Ratio	Probability	Statistics
Total marks available across all papers and exam boards	179	233	184	214	65	85
%	19%	24%	19%	22%	7%	9%
Total marks of questions that were significant and positive	8	44	18	12	4	7
%	9%	47%	19%	13%	4%	8%

Table 5.26: Positive significant results breakdown by topic areas of mathematics assessed

The results above show that where positive significant correlations are seen in the question-by-question analysis, these are most likely to be questions assessing algebra than geometry, and geometry more than the other areas. A chi-square test was conducted of the countable marks and their allocation using the following tables:

Observed		Number	Algebra	Geometry	Ratio	Probability	Statistics	
	pos.sig	8	44	18	12	4	7	93
	not pos.sig	171	189	166	202	61	78	867
		179	233	184	214	65	85	960

Expected		Number	Algebra	Geometry	Ratio	Probability	Statistics	
	pos.sig	17.34	22.57	17.83	20.73	6.30	8.23	93
	not pos.sig	161.66	210.43	166.18	193.27	58.70	76.77	867
		179	233	184	214	65	85	960

Table 5.27: Chi-square tests: marks gained in the different topic areas of mathematics assessed

The chi-square test of independence showed that there is a significant relationship between the marks allocated according to the area of mathematics tested (χ^2=33.3, p<.001, ϕ=0.193).

The analysis in this section concludes that there is an association between time spent on Hegartymaths topics and marks gained by the respective questions assessed in the GCSE, and that this relationship favours questions assessing algebra and geometry with most certainty, and number and statistics questions with less certainty. This analysis cannot claim that time spent on Hegartymaths affects performance in the areas of ratio or probability.

5.3 How is Hegartymaths used in the most successful schools?

In order to attempt to answer my final research question, a survey was conducted. All teachers of mathematics working at the UL schools in summer 2019 were asked to answer the following 19 questions using the multiple choice answers given in each question. The survey was made online using Microsoft Forms, which can be found here: https://forms.office.com/Pages/DesignPage.aspx?fragment=FormId%3DqmjQpA4JVU-pULG5XOocazxhWMt6hrRLrM6728VYFhJUNlZVUEpRQVhQM1o5QkFaMDFTVzhXVUtSSi4u%26Token%3D6c25ca146bdf42de887c81cdb1aef0ac. You can also see screenshots of each question as viewed online in Appendix H.

There were 106 responses to the survey from various schools. The results were then arranged into two groups: the responses of the schools that generated positive and significant correlations using Hegartymaths (from sections 4.2.3.1 and 4.2.3.2) were placed in one group, which I refer to as the more successful schools, and the rest of the responses in the other group. These results were analysed and using a chi-square test to highlight significantly different responses, the following findings could shed some light onto how the most successful mathematics departments use Hegartymaths. This will be examined further in the discussion section but below are the results that are of statistical significance:

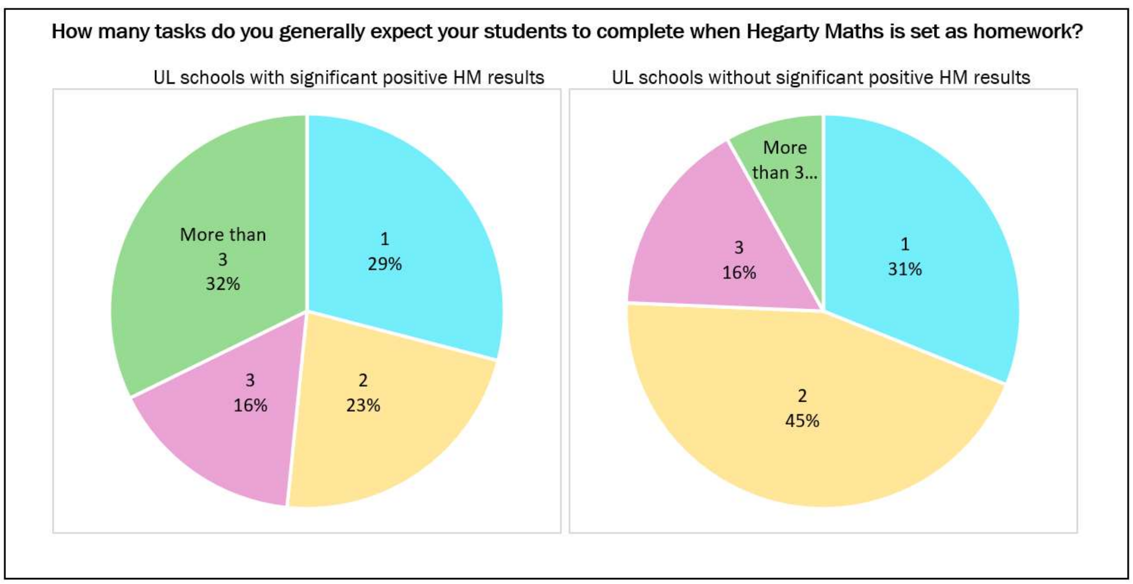


Figure 5.1: Results of the teacher survey grouped comparisons: *How many tasks do you generally expect your students to complete when Hegarty Maths is set as homework?*

		1	2	3	More than 3	No expectation	
Observed	Positive significant results using HM	9	7	5	10	0	31
	Non-significant results using HM	23	33	12	6	1	75
		32	40	17	16	1	106
Expected	Positive significant results using HM	9.358	11.698	4.972	4.679	0.292	31
	Non-significant results using HM	22.642	28.302	12.028	11.321	0.708	75
		32	40	17	16	1	106

Table 5.28: Chi-square test on the answers to the teacher survey: *How many tasks do you generally expect your students to complete when Hegarty Maths is set as homework?*

The chi-square test of independence showed that there is a significant difference between the responses made by schools that were most successful and the schools that did not yield positive significant results using Hegartymaths (χ^2=11.7, p<.020, ϕ=0.332).

It appears that schools which have most success with Hegartymaths use the online platform to set more homework tasks than the schools that did not yield positive and statistically significant results when using Hegartymaths.

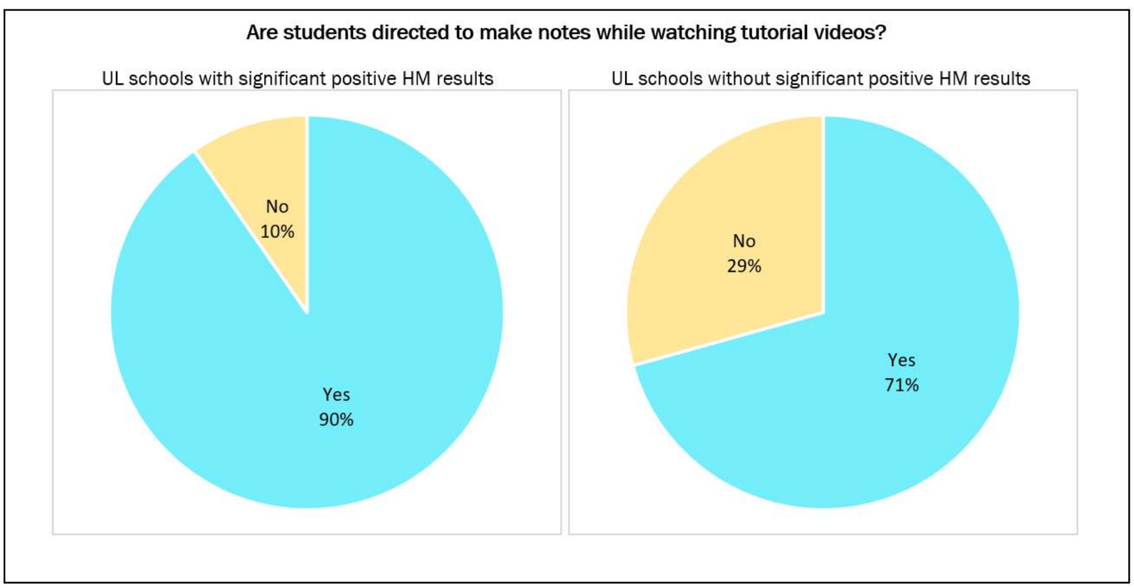


Figure 5.2: Results of the teacher survey grouped comparisons: *Are students directed to make notes while watching tutorial videos?*

		Yes	No	
Observed	Positive significant results using HM	28	3	31
	Non significant results using HM	53	22	75
		81	25	106
Expected	Positive significant results using HM	23.689	7.311	
	Non significant results using HM	57.311	17.689	

Table 5.29: Chi-square test on the answers to the teacher survey: *Are students directed to make notes while watching tutorial videos?*

The chi-square test of independence showed that there is a significant difference between the responses made by schools that were most successful and the schools that did not yield positive significant results using Hegartymaths (χ^2=4.70, p=.030, ϕ=0.211).

From the analysis above, it appears that schools which have most success with Hegartymaths use the online platform more to direct pupils to make notes while watching the instructional videos, as opposed to schools that did not yield positive and statistically significant results when using Hegartymaths.

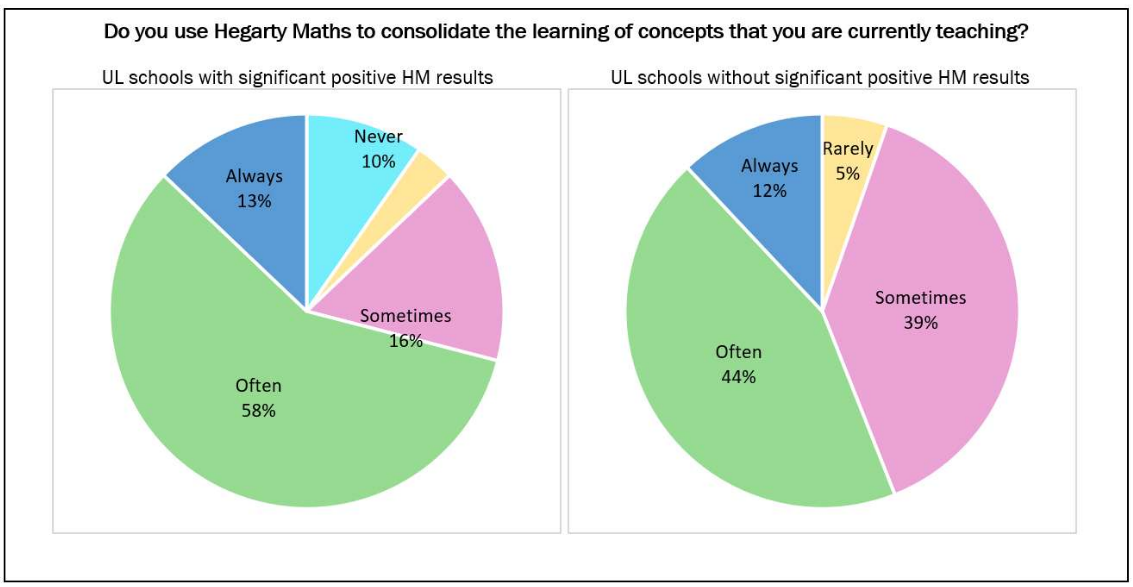


Table 5.30: Results of the teacher survey grouped comparisons: *Do you use Hegarty Maths to consolidate the learning of concepts that you are currently teaching?*

		Never	Rarely	Sometimes	Often	Always	
Observed	Positive significant results using HM	3	1	5	18	4	31
	Non-significant results using HM	0	4	29	33	9	75
		3	5	34	51	13	106
Expected	Positive significant results using HM	0.877	1.462	9.943	14.915	3.802	
	Non-significant results using HM	2.123	3.538	24.057	36.085	9.198	

Figure 5.3: Chi-square test on the answers to the teacher survey: *Do you use Hegarty Maths to consolidate the learning of concepts that you are currently teaching?*

The chi-square test of independence showed that there is a significant difference between the responses made by schools that were most successful and the schools that did not yield positive significant results using Hegartymaths (χ^2=11.85, p=.018, ϕ=0.334).

From the analysis above, it is inconclusive as to what schools that have most success with Hegartymaths do when using the online platform. It is either because they ‘never’ or more ‘often’ consolidate the learning that happens within the lesson using Hegartymaths, but the stark difference between the expected and observed results in the ‘never’ category is more likely to be the reason for statistical significance.

An example of the entire results from the survey can be found in Appendix I, and the full analysis of both statistically significant and non-significant differences of the above groups can be viewed in Appendix Q and Appendix R.

Chapter 6: Discussion

In this section I will discuss the findings from the previous chapter. This chapter will be comprised of three sections, each of which discuss the findings in relation to my research questions.

For each section, where applicable, I will draw on the literature from my literature review to provide possible explanations for each of the significant results. Where appropriate, I will also use my experience of my own and others' teaching of mathematics and use of Hegartymaths. Each section will also include the limitations of the research and highlight potential further research.

6.1 To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE?

In this section I will focus on the parts of my findings in relation to the research question: *'To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE'*. These will be broken into two subsections. The first of these are the two large quasi-experiments where Hegartymaths schools were compared to non-Hegartymaths schools, as well as the large quasi-experiment wherein United Learning schools (who use Hegartymaths) were compared to the rest of the mainstream secondary schools in England. The second is the comparison between United Learning schools, based on performance and time spent on Hegartymaths.

6.1.1 Quasi-experiments 1 and 2

The following two sections discuss the findings of the quasi-experiments that compared the large dataset gathered from the gov.uk website, before the limitations and recommended future research are discussed.

6.1.1.1 Quasi-experiment 1: A comparison of performance between schools that use Hegartymaths and schools that do not use Hegartymaths

The findings of the quasi-experiment that studied mainstream secondary schools in England and placed them into a control group which was comprised of the schools that do not use Hegartymaths, and a treatment group comprised of the schools that do use Hegartymaths, were inconclusive. If one were to look at attainment figures of the mathematics element alone, the statistically significant results observed would indicate that Hegartymaths does not have a positive impact on GCSE performance. However, statistically significant results were also observed when comparing the two groups of schools in relation to non-mathematics specific measures: schools that do not use Hegartymaths outperform schools that do use Hegartymaths in terms of attainment overall; in particular the attainment of pupils with high prior attainment favours non-Hegartymaths schools. Therefore, when considering Attainment 8 figures for the mathematics element, it would be expected that non-Hegartymaths schools would again do better.

Further, the difference between the Progress 8 score of the whole school between groups, and that of Progress 8 within the mathematics element were identical: 0.03. This means that pupils in non-Hegartymaths schools make 3% of a grade more progress than schools that do not use Hegartymaths in both the pupils' subjects overall, and also in the mathematics grade. As would be expected of such a small difference, these results were statistically insignificant.

The statistical insignificance of the Progress 8 comparison could, in fact, be significant when considering the prior data. It was shown that schools that do not use Hegartymaths inherit a statistically significant and stronger cohort, in terms of the prior data at KS2, as well as fewer pupils that are disadvantaged, fewer pupils who have English as an additional language and more pupils who have English as their first language, all of which were statistically significant. Progress 8, while a much fairer and more meaningful way to compare the teaching and effectiveness of the school than the Attainment 8 figures (Leckie and Goldstein, 2017), does not reflect the context of the pupils which, according to the figures, favours schools that do not use Hegartymaths.

Measures of progress in England have changed multiple times in recent years. In 2002, 'value-added' was introduced (VA1). Schools' scores were derived by measuring the difference between pupils' GCSE scores in eight examinations with the national median score of pupils who achieved the same as them at the end of Key Stage 2 (~11years old). Criticisms were made as this measure did not consider differences in pupil socioeconomic and demographic traits, which should be considered as they had been known to be indicators of GCSE performance even after adjusting for prior data (NAO, 2003; Ray et al., 2009). After receiving these criticisms, VA1 was replaced in 2006 with contextual value added (CVA), which still measured progress in relation to Key Stage 2 results but it was a more flexible function that included age, gender, ethnicity, socioeconomic status and other various school characteristics in the calculations. Among other reasons, the most significant criticism cited by the Government in relation to CVA, was that by considering the pupils' demographics and socioeconomic backgrounds in these measures, CVA aided in creating low expectations and aspirations for pupils in the 'disadvantaged' category (DfE, 2010d); there have not been many challenges to these claims within the literature (Leckie and Goldstein, 2017). Two measures were used in place of CVA from 2011: value added (VA2) and expected progress, (EP). VA2 was essentially a return to VA1 but it was EP that became the headline measure for progress in England. EP measured the proportion of pupils who were deemed to have made expected progress; this was defined as three or more national curriculum levels between KS2 and KS4. It was reported separately for English and mathematics in 2014 that 72% of pupils in English and 66% in mathematics made expected progress (DfE, 2015c). Again, this was a return to pupils' backgrounds not being taken into consideration and EP has been criticised for having bias and favouring the pupils who have high prior attainment (Dracup, 2015; Stewart, 2015).

Progress 8 (P8), which is the current measure of progress, was introduced in the 2016 league tables and marks the return to measuring the value a school has added to a pupil's grade by benchmarking this with the student's prior data. This is a welcome change from the EP measure as it should, in theory, no longer penalise schools that serve a high number of low-attaining pupils (Gill, 2018). It is different from VA1 and VA2 as the list of approved subjects that make up the P8 score are more academic: English, Maths and a further six 'approved subjects' (DfE, 2016c) are used to make up the score. However, like VA1 and VA2 and in contrast to CVA, the P8 score does not make any adjustments to account for socioeconomic or demographic characteristics between each school's inherited cohorts. By neglecting to adjust for these differences, P8 continues to penalise schools serving disadvantaged communities (Leckie and Goldstein, 2017; Gill, 2018). There is evidence that various groups perform better on P8 measures, including girls and those of Chinese ethnicity (Andrews, 2017), non-free school meals students (Andrews, 2017; Sherrington, 2017), and non-Pupil Premium students (Thomson, 2017b). Another criticism of the P8 measure is that the evidence shows it favours selective schools (e.g., Allen, 2016; Andrews, 2017), which is again linked to the assumption that selective schools inherit a much higher-attaining intake (Gill, 2018).

Returning to the findings of the quasi-experiment, the literature above indicates that the schools who use Hegartymaths may have been penalised by the use of the P8 measure. Nevertheless, the findings indicate that the schools using Hegartymaths were able to produce statistically similar results to the schools that did not use Hegartymaths, which leads me to suggest that schools using Hegartymaths make at least the same amount of progress in mathematics as those who do not use Hegartymaths.

6.1.1.2 Quasi-experiment 2: A comparison of performance between United Learning schools that use Hegartymaths with the rest of mainstream secondary schools in England

The control group in this quasi-experiment are the mainstream secondary schools in England that sit outside of the 37 United Learning schools in my sample. This includes schools that do use Hegartymaths and others that do not, and although this implies I cannot use the findings to draw conclusions about the extent to which Hegartymaths aids performance at GCSE, I can provide some insight into how United Learning schools that use Hegartymaths perform in relation to the control group. This is an important part of my study as the way in which these schools operate, following guidance from United Learning, is similar and one which I am very familiar with, being part of a United Learning school myself. It follows that the way in which Hegartymaths is viewed and used, which is discussed during the meetings of heads of departments within these schools three times a year, is also similar. The findings are also important to put the 37 United Learning schools in my sample into context, which is key for the rest of the study that uses data generated from these schools alone.

As with the quasi-experiment above, I observed statistical differences in the cohorts inherited by the control and treatment groups. The United Learning schools in my sample had cohorts that showed statistical differences in the following areas: more low-attaining and fewer high-attaining pupils; more pupils that were disadvantaged; more pupils that had English as an additional language, and fewer pupils that had English as their first language. In terms of performance however, United Learning schools reversed the trend of the prior data and outperformed the control group significantly on a school-wide basis in the following categories: the P8 measure for disadvantaged pupils, and both the Attainment 8 and P8 measures for pupils with low prior attainment. For the mathematics element, the P8 measure indicated that United Learning schools performed by 0.13 of a grade more, on average, than the control group although this was not deemed statistically significant. In terms of the P8 score for mathematics for pupils that are disadvantaged, United Learning schools outperformed the control group by 0.207 of a grade, which was of statistical significance.

In a similar vein and using the literature described in section 6.1.1, an argument can be made that the measures used to compare the groups do not favour United Learning schools. Despite this, the findings are positive for United Learning schools that use Hegartymaths to aid GCSE performance, which are particularly significant for low attaining pupils and for disadvantaged pupils.

6.1.1.3 Quasi-experiment 1 and 2: Limitations and recommendations

There are several limitations in the quasi-experiments described above. These will be discussed in turn, where I will recommend adjustments to the research design to increase the internal validity of the findings of future research and as such, attempt to provide a better way to truly reflect the phenomena under study, which is Hegartymaths. Issues of external validity are not included as the entire population was considered.

The issues highlighted by using P8 measures above (section 6.1.1) would be largely eradicated through the application of CVA, if this calculation could be applied to the mathematics element. Alternatively, the study could be repeated in a similar fashion to various subsets of the population where the schools that make up each sample have very similar students, both in terms of prior data and demographic and socioeconomic backgrounds. This would also provide insight into whether Hegartymaths is more suited to schools with specific contexts. If the schools selected to be studied have very similar cohorts, this also carries the benefit of raising the profile of attainment figures as plausible measures, which in turn have the benefit of measuring all pupils as opposed to the P8 scores that do not account for the pupils without KS2 data.

These studies in their current form also only consider if Hegartymaths is used by the schools or not. In reality, not all of the schools that use Hegartymaths devote the same amount of time to learning through the online platform. A more sophisticated version of the same study could come about if all the schools' Hegartymaths data were available. This would enable correlations to be calculated between the progress measure and the time devoted to pupil learning through Hegartymaths, which would further answer the question of the efficacy of Hegartymaths.

As well as differences in usage in terms of time, other discrepancies that make this a quasi-experiment rather than a scientific one are that not all schools have the same experience or training opportunities in using Hegartymaths, which could lead to significant variations in the experience a pupil will receive. This will always be a limitation in any study into this subject matter, unless the entire curriculum was taught through Hegartymaths only. This is something I would not advocate for ethical reasons as well as for the reason that Colin Hegarty, who developed the website, had always intended for Hegartymaths to work alongside the teacher and not replace the teacher.

Comparing United Learning schools with the rest of the mainstream secondary schools could also be problematic and important to acknowledge, as there could be differences between these two groups when considering the quality of the teaching and the way in which teachers use Hegartymaths, to name just two potentially significant factors. In studies conducted on pedagogical approaches, specific teacher strategies and interventions, the role the quality of the teacher plays - alongside the chosen pedagogical approach – could be hugely influential. It is almost common sense that the quality of the teacher delivering the content, regardless of approach, will impact on student outcomes, and it has been cited that a crucial factor of teacher quality is teacher subject knowledge (Coe et al., 2014).

Another crucial factor is pedagogical subject knowledge, which is distinct from knowledge of content (Shulman, 1987) and concerns the translation of the teacher's subject knowledge into something that students can access and learn (Hodgen et al., 2018). In a study of the effects of content knowledge and pedagogical content knowledge, it was found that although both forms of teacher knowledge were strongly correlated, pedagogical content knowledge was identified as a stronger predictor in relation to student progress (Baumert et al., 2010). The effects of pedagogical content knowledge were attributed to the choice and delivery of tasks, the relation between instruction and curriculum (which was also the case for content knowledge), and the flexibility to adapt instructions according to specific learners (Baumert et al., 2010). It follows that if, for example, United Learning's recruitment process attracts teachers with stronger content knowledge, or that the continual professional development offered by such a large multi-academy trust enables teachers to develop more secure pedagogical subject knowledge, the resultantly better teachers could skew the results in United Learning's favour.

6.1.2 Comparing United Learning schools with the amount they use Hegartymaths

In this section, I describe the findings of examining the data, using both the performance data gathered from the gov.uk website and the Hegartymaths data for the 37 United Learning schools provided by Hegartymaths. The Hegartymaths data enabled me to conduct a deeper analysis of the performance measures for the mathematics element, as I was able to look for correlations between Hegartymaths use, in terms of both the time spent on watching the tutorials and the time spent by pupils completing the quizzes, with GCSE performance. These findings contribute towards answering the research question: *'To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE'.* The prior data analysed in section 6.1.1.2 described the context of the United Learning schools in my sample and this will be used to offer potential variations on the study for future research. As well as this, the section is concluded by describing the limitations to the research design, which are largely entrenched in the data that was provided.

6.1.2.1 To what extent does the time spent on the quizzes, videos and Hegartymaths overall have an impact on student outcomes at GCSE for pupils of United Learning schools?

Statistically significant and positive medium correlations for the time spent on Hegartymaths overall (pupils' time on the quiz and videos) when considering attainment, were found for pupils who are disadvantaged and pupils with middle prior attainment. When considering progress, this was the same case for pupils who are disadvantaged, pupils with middle prior attainment and also for students with high prior attainment. The progress scores in particular show that Hegartymaths has been effective for pupils to achieve higher GCSE grades if they are disadvantaged, or have middle or high prior attainment.

When analysing if time spent on the quiz or watching the video tutorials affected the performance of pupils at GCSE, it was clear that the time spent on completing quizzes was a more significant use of the pupils' time overall. After correlating with attainment, both the quiz time and video time were deemed significant and positive for pupils that are disadvantaged but the results were most interesting when analysing the data of the pupils with low and middle attainment. The time spent on the quiz was most significant for pupils that have middle prior attainment, which was unsurprising as this is in line with the overall findings that favour time spent on the quiz element. However, the time spent on the videos seemed to influence the pupils' GCSE performance for those with low prior attainment more than the time spent doing the quiz. This was the only measure that indicated that some pupils should prioritise watching the video tutorials if they are to see a statistically significant increase in their attainment. A possible explanation for this is that pupils with low prior attainment learnt more content through Hegartymaths than they otherwise would. Pupils with low prior attainment are usually placed in the lower sets in the schools that do set students. The rationale here is that for pupils to access the hierarchical nature of the lessons in mathematics they receive, they should be placed in groups where the pace of learning content is best suited to the majority of individuals within that class. In the case of lower groups, pupils learn at a slower pace, which results in the students not learning all of the curriculum content that they are tested on in the GCSE. Hegartymaths provides an opportunity for those pupils who want to learn the material they have missed to study this content online, outside of the classroom. These pupils cannot successfully attempt the quiz without learning the content first, and if they have not learnt this in class, they could have achieved a significant amount of extra marks on these topics in the exam after learning the content through Hegartymaths.

When considering the progress data for the mathematics element, the time spent on the videos was not deemed to be significant for any of the correlations calculated in any of the six categories. Conversely, the time spent on completing the quiz was found to be statistically significant for progress overall, for the disadvantaged pupils and for pupils who had both middle and high prior attainment. The time spent on the quiz did not return significant results in only the categories of pupils who are non-disadvantaged and those with low prior attainment, which leads me to conclude that time spent completing Hegartymaths quizzes has a significant effect on pupils' performance in GCSE mathematics.

There are a couple of possible broad explanations that I would like to explore as to why the quiz element is the more effective use of pupils' time. They are based on how the teacher incorporates Hegartymaths in their classroom and how the pupils use this accordingly, as well as the role that practice plays, which is necessary for pupils to learn mathematics.

The most common way I have seen Hegartymaths used in schools, and that which is verified from the results of this comparison, is by using Hegartymaths for quizzes: the total time per pupil of the 37 United Learning schools spent on Hegartymaths was 14.5hrs for the quiz and 3.3hrs for watching the videos. The extra time spent by pupils on the quiz in each school allows for a larger degree of variation between schools, which can have an effect on the statistical tests used. A possible explanation is that this extra potential for variance is why the correlations indicated statistically significant results for the quiz as opposed to the time spent on watching the tutorials. However, pupils who have watched the video tutorial or learnt the content in class and can therefore access the quiz, are also far more likely to spend more time on the quiz element if they were not successful the first time. This could be because the teacher has directed pupils to achieve a minimum score on the assessment for the homework to be considered complete, which is common practice amongst United Learning schools, or it could also be because a student wants to ensure they have corrected what they did not get correct, to achieve 100%. Either way, a student is far more likely to attempt the quiz again in these instances rather than re-watch the video. The most likely reason for this is that pupils have realised the mistake they had made when the correct answer was shown. It is also very common for pupils to understand specific concepts and procedures sufficiently well enough to get full marks, but not to achieve 100% due to imprecision or a lack of concentration. This extra practice that pupils engage with on the questions they were not most comfortable with could be key in explaining why time spent on the quiz element of Hegartymaths is more significant than watching the videos.

While practice tests can promote learning by helping students memorise facts and figures (Avvisati and Borgonovi, 2020), it is common to encounter criticisms of these low-stakes tests by parents, teachers and educators as they are deemed irrelevant for the real world and can be seen to narrow the curriculum (Amrein and Berliner, 2002; Nichols and Berliner, 2007; Watanabe, 2007). The expectation of some students to repeat the questions and achieve a high score on the quizzes found on Hegartymaths - which can be seen as practice tests - can be argued to divert valuable time away from learning, as teachers might 'teach to the test' and their students will 'learn for a test' (Crocco and Costigan, 2007; Nelson, 2013). However, I am more inclined to believe the consistent experimental evidence that enhances learners' ability to retain and recall information through administering low-stakes retrieval tests (Carrier and Pashler, 1992; Carpenter and Delosh, 2006; Kang, McDermott and Roediger, 2007; Karpicke and Roediger, 2008; Karpicke and Blunt, 2011; Adesope, Trevisan, and Sundararajan, 2017). Either way, if this extra time pupils choose to spend on answering specific quizzes enables them to learn the mathematics needed to perform for a test, or the extra marks gained are attributed to the fact that they have become better at retaining and recalling information, my argument is that this is why the time spent on quizzes is more significant than watching the videos.

6.1.2.2 United Learning schools comparison study: Limitations and recommendations

There are several limitations to the claims made in section 6.1.2.1 due to certain assumptions that needed to be made about the data provided. Some of these assumptions can be eradicated with a more detailed dataset, both from Hegartymaths and the gov.uk website for potential future studies, which I intend to describe in this section.

Firstly, the data found on the gov.uk website could lead to some problems justifying the claims made when considering the breakdown of pupils with low, middle and high prior attainment. These figures are reported across the eight subjects needed to calculate both the attainment and progress measures, as opposed to the P8 and A8 scores of the mathematics element across the school and those of students who are disadvantaged or not. The assumption needed to make conclusions regarding pupils' prior attainment is that the overall school results in relation to pupils with low, middle or high prior data correlate with the performance seen by the same pupils within mathematics. As such, it is important to recognise that the claims according to pupils' prior attainment do not carry the same weight statistically as those concerning whole school measures and the measures according to disadvantaged pupils. The correct breakdown of these statistics, if available in future, would enable the test to be run in the same way and generate results of a future study that does not contain this assumption.

Secondly, the Hegartymaths data provided was not broken down in a way for me to know the time spent specifically by disadvantaged pupils or those with low, middle or high prior attainment. This resulted in me having to use the United Learning schools' usage statistics for the entire school for all of the separate categories in order to correlate these with the performance measure for specific categories. This is not as problematic as the issue described in the previous section as the product moment correlation is not affected by coding. This means that although the statistics used might not be accurate, the assumption here is merely that the different subset of pupils contributed to the overall statistics by the same factor. For example, if it was known that the time students spent overall on Hegartymaths by pupils of school A was distributed in the ratio 2:3 according to whether pupils were disadvantaged or not, the same distribution is assumed for the remaining schools in the sample. Considering that there were 34,426 pupils grouped into 37 school groups before the correlations were calculated, and that the characteristics of disadvantaged and non-disadvantaged pupils in these schools are similar, this assumption should not considerably limit the validity of the claims. However, if the Hegartymaths data included a code to identify pupils of different categories, this would allow the test to be run in the same way with more accurate results in a possible future study.

Thirdly and finally, the Hegartymaths data for all the United Learning schools in the sample do not represent a pupil's journey through their secondary education accurately, as data from different pupils from all year groups were used as opposed to just the Yr11 students who took the exam (see section 4.2.4 for more details). The main reason behind this decision, and to use aggregated data, was that all schools in the sample have not been using Hegartymaths throughout the 5 years of secondary mathematics education prior to the GCSE examination. However, all the mathematics the pupils have learnt from Hegartymaths contribute to their GCSE performance and I wanted statistics to capture this entire journey, rather than limiting the data to solely the learning in their final year. Using the Yr11 statistics alone would have been more problematic, especially in the question-by-question analysis that follows, as the data would be skewed towards the topics that are usually left for pupils to learn in Yr11. In future years when this is available for all schools, a similar study could track a year group over five years in a more accurate way, although this would still contain some anomalies such as pupils not attending the same school for their entire secondary education, or schools making large changes to their schemes of work that would alter the time spent by pupils on specific topics and which could skew the data. A more detailed approach would be to track pupils on an individual basis first, before correlating this with individual performance. If this proves to be ethically feasible and permission can be granted from all schools involved, as well as Hegartymaths, conducting the study in this way would avoid the issues that arise from using aggregated data. It would be quite a time-consuming national study but would however offer greater validity to the claims in this study and is something I would recommend.

6.2 Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?

This section refers to the findings found in section 5.2, and possible explanations are given for the observations found in relation to my second research question: *'Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?'* In order to answer this, I assessed all of the 37 United Learning schools' pupils' performance in each question on both the AQA and Edexcel Foundation and Higher Examinations. This entailed analysing 219 questions from 1142 pupils entered for AQA, and 212 questions from 4195 pupils entered for Edexcel. The outcomes were then combined in several different ways, before further correlations were calculated to assess the efficacy of Hegartymaths according to:

a) School;
b) Exam board;
c) Tier of entry: foundation or higher;
d) Type of paper: calculator or non-calculator;
e) Type of question according to the assessment objective tested for;
f) Area of mathematics tested: Number, Algebra, Geometry, Ratio, Probability and Statistics.

The limitations of the different parts of this section of the study (as listed above) are similar as they arise from the initial question-by-question analysis. As such, these will be discussed first as well as offering alternative approaches that could be used for future studies. After describing the limitations, the conclusions drawn from this section of the study will be discussed.

6.2.1 Question-by-question analysis: Limitations and recommendations

For this analysis to occur, a vast amount of data were retrieved from multiple sources, which is almost certain to contain errors and therefore limitations. First, the examination boards AQA and Edexcel, provided data after marking a combined 16,011 exam papers, each of which comprised of 431 different questions, across both tiers and boards. Although the accuracy of the examiners in mathematics is considered very good on the whole, human error will have led to a small degree of inconsistency in marking. Further, the marks allocated to each pupil for each question, or subset of a question, were not broken down where the questions assessed pupils' competence on multiple areas of mathematics and across several assessment objectives. In these instances I had to code the question according to where the majority of marks were given, as I could not differentiate between how many marks were awarded for specific areas of mathematics or which assessment objectives were being tested for. Further, the marks achieved by each pupil contribute to their attainment only in mathematics, which is not a true reflection of progress as it does not consider the pupils' prior attainment as described by the literature found in section 6.1.1.1.

Second, the schools' Hegartymaths data raised some discrepancies between the amount of Hegartymaths accounts and the number of pupils on roll at the end of Key Stage 4, as described in section 5.1.2.3. A decision had to be made to use the amount of accounts as opposed to the pupils on roll in order to calculate the time spent on Hegartymaths per pupil, but this too carries an error. As described in section 6.1.2.2, the data used here also does not represent a pupil's journey through their secondary education accurately because the data from different pupils of all year groups were used, as opposed to just the Year 11 students who took the exam (see section 4.2.4 for more details). The assumption that leads from using all the pupils' Hegartymaths data in the calculations of correlations concerns the fact the exam boards test pupils in foundation and higher separately. There are some 'cross-over' questions that are found in both tiers but there are also questions that are only found in each tier. The time pupils spent on Hegartymaths, which was used to calculate the time each pupil spent on a particular skill before the correlations were carried out, does not distinguish between whether the pupils were eventually entered into the foundation or higher examination. As mentioned in a similar instance in section 6.1.2.2, the product moment correlation is not affected by coding, so the assumption of using the entire school's data is a valid one, provided that the proportion of total time spent on a task is distributed in each school in a similar way to students of each tier, regardless of whether higher tier students have contributed more to the overall time or if the inverse is true.

Third, the final source of data for this analysis was retrieved from both Hegartymaths.com and Pinpointlearning.co.uk to assign the most associated Hegartymaths clips to the questions assessed in the GCSE. This itself is subjective and problematic as in reality the learning achieved through multiple clips would contribute to students gaining marks in each question and not just the most associated clips. Further, in certain instances, discrepancies were found between the websites, which led to the decision to leave these out of the analysis, as described in section 4.2.2.

Another limitation occurs whilst assessing if Hegartymaths is more suited to a particular area or type of question assessed. To gain more power in the conclusions drawn from this study, a compromise was made by combining data from all tiers and both exam boards. In the scenarios where the total available marks in each of the categories tested differed across boards and tiers, this did not affect the correlations observed because, as mentioned previously, coding does not affect the product moment correlation. However, there is an argument that because of the variance in difficulty pupils encountered in questions of the same category across different exam boards, these should not be combined. Contrastingly, I made this decision because the differences in the median expected difficulty should not "represent substantive differences" across exam boards, as seen in the Ofqual report evaluating the difficulty across exam boards a year prior to the Summer 2019 Examinations (Holmes, Howard and Stratton, 2017).

The recommendations I would suggest for future research in this section of the study would be similar to those described in section 6.1.2.2. Essentially, a greater depth in description of the data for more accurate allocation of time spent on Hegartymaths and of marks gained for the various categories investigated, as well as being able to correlate according to individual pupils' data, would allow for more precise conclusions to be drawn.

6.2.2 Conclusions from the correlations calculated according to school, exam board, tier and type of paper

The results observed in sections 5.2.1.1, 5.2.2.1, 5.2.3.1, 5.2.3.2 and 5.2.3.3 provided conclusions that do not offer a strong argument as to which exam board Hegartymaths is more aligned to, which in itself is reassuring, as the difficulty of exam boards should not vary significantly and the hours spent per pupil on each of the associated clips that were examined were comparable between exam boards: 125.61 minutes for AQA and 159.55 minutes for Edexcel. The school-by-school basis correlations indicated that there are more statistically significant and positive results for schools that chose AQA but more statistically significant and positive results were observed for Edexcel when the question-by-question correlations are taken into consideration.

The data was also inconclusive for tier of entry and whether the paper permitted the use of a calculator or not. Sections 5.2.4 and 5.2.5 only returned statistically insignificant results, so no explanations are offered in this discussion as the nature of the results are in line with what is expected.

6.2.3 Conclusions from the correlations calculated according to the assessment objective

Some possible explanations of the findings described in section 5.2.6 are discussed in this section. The results indicated that time spent on Hegartymaths significantly and positively affected the marks pupils gained in the GCSE examination of AO1 and AO2 overall, with a slightly stronger medium correlation favouring the questions testing AO1. This was due to AO1 marks proving to be significant across both the higher and foundation papers, whereas AO2 marks were only significant in the higher paper. There were no statistically significant correlations observed across AO3 marks, either separately within each tier or overall. In the question-by-question analysis, considering only the questions that generated positive and significant results, AO1 questions were again most frequently seen, followed by AO2, even when taking into account the distribution of total marks according to the assessment objectives.

Questions that test for AO3 are known to be the type students find most challenging and these items were found to be more difficult than the overall assessment standard when analysed by Ofqual during the summer 2017 examination series (Holmes, Howard and Stratton, 2017). This could partly provide an explanation for the findings described in section 5.2.6, however the fact alone that they are more difficult is only a partial explanation. In fact, questions that students find harder are the ones they are most likely to devote more time to if the teacher has directed pupils to achieve a certain benchmark score on the

Hegartymaths quiz, as previously described. The greater amount of time spent on these AO3 questions could lead to negative correlations, but this was only the case for one AO3 question across all 431 analysed.

Looking at this question in more depth, and the most closely associated Hegartymaths quiz question, can give us an insight into why this might have occurred:

6 Harry is planning a holiday for 4 people for 7 days.
Here are the costs for the holiday for **each person**.

Travel	£150
Hotel	£50 for each day
Spending money	£250

Work out the total cost of the holiday for 4 people for 7 days.

£..
(Total for Question 6 is 4 marks)

Figure 6.1: Question 6 on the May 2019 Edexcel Foundation Non-Calculator exam

Tara looks up hotel room prices for a holiday.
A hotel has a 25% off sale on its prices.
A VAT charge of 20% must be added on at the end of the transaction after any discount.
If the regular price of a room is £90 per night, how much will Tara pay for 5 nights?

Figure 6.2: Question 5 from Hegartymaths quiz 752 – Money (problem solving 1)

The question above, selected from Hegartymaths, was the closest question I could find resembling the exam question out of the 7 asked in quiz 752, which was the associated clip used in the analysis. On the surface, I would categorise both of these questions as equally difficult. If pushed, I would assume that the Hegartymaths question is more difficult than the Edexcel question as it requires pupils to have additional mathematical knowledge of percentages. However, what aligns the Edexcel question to AO3 is that pupils are required to translate this mathematical problem into a process that is not a routine AO1 problem. It is not a question of difficulty, but more the case that pupils are unlikely to have seen a similar question to the Edexcel one, whereas I would assume the Hegartymaths question is more familiar to them, as this format has been repeated throughout the Hegartymaths quiz. Using the terms conceptual and procedural knowledge, as defined in the literature review, the Edexcel question tests pupils' conceptual knowledge moreso than the Hegartymaths question. This leads me to conclude that Hegartymaths has proven to be more effective for AO1 questions. The 'rigid' nature of Hegartymaths, wherein pupils are exposed to good quality but similar, routine problems repeatedly when they have retaken the quizzes multiple times, enhances pupils' ability to achieve more on questions that test for procedural knowledge: the AO1 questions.

6.2.4 Conclusions from the correlations calculated according to the area of mathematics tested

The findings from section 5.2.7 are discussed in this section, where the results of the question-by-question analysis were categorised into areas of mathematics, as defined by both AQA and Edexcel. Statistics, Geometry, Algebra and Number were the areas that positive and medium correlations were observed, in order of strength from highest to weakest. It was also noticed that Algebra contributed the most significance when the total marks available were considered.

Considering that there is a strong possibility that Hegartymaths is not suited to AO3 questions as suggested in the previous section, a further analysis was conducted of which assessment objectives these areas of mathematics assessed. The table below shows the breakdown of marks from only the questions that were statistically significant from the question-by-question analysis and the distribution of AO1, AO2 and AO3 within the areas of mathematics:

	Number			Algebra			Geometry			Ratio			Probability			Statistics		
	AO1	AO2	AO3	AO1	AO2	AO3	AO1	AO2	AO3	AO1	AO2	AO3	AO1	AO2	AO3	AO1	AO2	AO3
Marks pos.sig	5	3	0	23	10	11	11	2	5	12	0	0	3	1	0	5	2	0
% of area	63%	38%	0%	52%	23%	25%	61%	11%	28%	100%	0%	0%	75%	25%	0%	71%	29%	0%

Table 6.1: Statistically significant results breakdown of marks gained by area of mathematics and assessment objective tested in the Summer 2019 GCSE mathematics examination series

The heavily weighted marks towards AO1 and AO2 in the areas of Number and Statistics go some way to explain why these areas were deemed statistically significant if we are to accept that Hegartymaths is more aligned to AO1 and AO2 questions. However, there was an even higher proportion of AO1 and AO2 marks in Ratio and Probability questions, which were not seen to be affected by Hegartymaths.

The table below shows the breakdown of marks from all the 431 questions analysed, and the relation these have to those that were statistically significant:

	Number			Algebra			Geometry			Ratio			Probability			Statistics		
	AO1	AO2	AO3	AO1	AO2	AO3	AO1	AO2	AO3	AO1	AO2	AO3	AO1	AO2	AO3	AO1	AO2	AO3
Overall	101	28	50	115	78	40	37	48	99	77	32	105	17	28	20	11	55	19
% of area	56%	16%	28%	49%	33%	17%	20%	26%	54%	36%	15%	49%	26%	43%	31%	13%	65%	22%
pos.sig/ overall	5%	11%	0%	20%	13%	28%	30%	4%	5%	16%	0%	0%	18%	4%	0%	45%	4%	0%

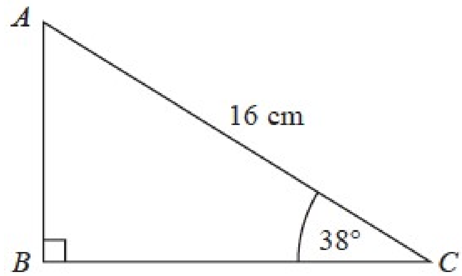
Table 6.2 All results breakdown of marks gained by area of mathematics and assessment objective tested in the Summer 2019 GCSE mathematics examination series

The Ratio marks offered by the exams were skewed by the amount tested for AO3. This was also the case for Geometry, where very little success was also seen for AO2 and AO3 questions. However, the AO1 marks were better-answered in Geometry rather than Ratio when considering the time pupils spent on Hegartymaths and the total marks available for each; this re-enforces the argument that Hegartymaths is more suited to helping students perform in areas of Geometry than the topic of Ratio.

This was quite surprising to me at first because I would not have expected Geometry to have been supported as significantly as it was by time spent on Hegartymaths. My experience in the classroom suggests that there are many similarities to teaching approaches across mathematical topics. Providing students with questions to practise after content has been taught, for example, is relevant for both the topics of geometry and algebra. However, I am unlikely to give repetitive examples of the same question on circle theorems for the purpose of practice, where the only difference between the questions is that new numbers have been substituted. This is because the crux of the learning for this particular topic is that students are able to recognise and select the circle theorem they need in order to solve the problem. For quadratic equations however, giving the same question with different numbers is an ideal way for pupils to get to grips with the method and for it to become 'procedural'. Experiences such as this would suggest that there is likely to be extensive literature on the different teaching pedagogies across different mathematical topics. However, the research field seems to be limited in terms of how to teach students differently for specific topics, otherwise known as the 'technicalities of teaching' (Nunes, Bryant and Watson, 2009).

Examining some more of the questions that were deemed positive and significant, as well as their associated Hegartymaths clips, support is shown for the hypothesis that Geometry questions are indeed aided by Hegartymaths more significantly if they are of a nature that pupils have been exposed to before, thereby becoming routine problems that test for procedural knowledge.

ABC is a right-angled triangle.



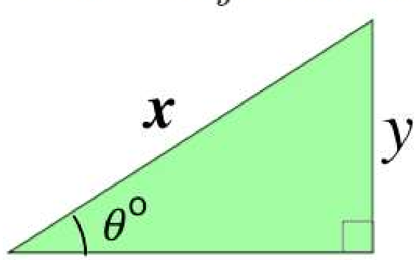
Calculate the length of *AB*.
Give your answer correct to 2 decimal places.

....cm

(Total for Question 5 is 2 marks)

Figure 6.3 Question 5 on the June 2019 Edexcel Higher Calculator Paper 2 exam, which was also Question 24 on the June 2019 Edexcel Foundation Calculator Paper 2 exam

Given that y = 7 cm and θ = 45°, work out x rounded to 1 DP.



The diagram is not drawn accurately.

Figure 6.4 Question 4 from Hegartymaths quiz 509 – Trigonometry (find side) (1)

The Hegartymaths question is identical in procedure to the exam question, and would also be presented in exactly the same way if the triangle were reflected and the numbers were placed in the diagram, which are two skills that do not frequently cause pupils difficulty in my experience. What is also interesting in the selection above is that Edexcel deemed this question to be an AO1 item on the higher paper but an AO2 item on the foundation paper. Does this mean that the assigned assessment objective is dependent on whether pupils are taking higher or foundation? Although this is a question to be answered at another time, it lends weight to the argument that - despite it being AO1 or AO2 - it is a routine problem for students who have completed the Hegartymaths quiz as they have been exposed to this format of question repeatedly, thereby becoming a test of their procedural knowledge.

The table also explains the efficacy of Hegartymaths for Algebra questions. The breakdown of proportion of marks allocated by area shows that the smallest proportion of AO3 marks were found in Algebra. This also bodes well for Hegartymaths as a platform that wishes to convince schools that their pupils' performance will be enhanced if they use Hegartymaths as, not only were the majority of AO1 and AO2 marks across the paper found on questions of Algebra, but the majority of marks across the paper were also on Algebra.

As far as questions testing pupils' Number or Statistics knowledge are concerned, the extra analysis was not seen to provide more answers other than that here, too, AO1 questions were seen to be where most of the significant results arose from, followed by AO2 questions.

The breakdown of how marks are allocated by area of mathematics is likely to change year on year, however the Department of Education has directed exam boards to have set distributions of marks assigned to the assessment objectives. The impact this could have is that Geometry, for example, in a different year where more AO1 questions are seen in this area, could be even more significant in relation to the efficacy of Hegartymaths. The conclusions drawn from this section are therefore that Hegartymaths is more aligned to topics that lend themselves well to the AO1 and AO2 questions. Some topics from my experience do lend themselves well to routine problems that test procedural knowledge, in areas such as Algebra, Number and Statistics, and so these are the ones I would focus the use of Hegartymaths on with my pupils. For Geometry, Ratio and Probability, I would focus the use of Hegartymaths on only the topics within these areas I deem as testing pupils' procedural knowledge, knowing that I need to find ways other than Hegartymaths to help them answer the more conceptual, non-routine AO3 questions across all topics, and in particular for Probability and Ratio questions.

6.3 How is Hegartymaths used in the most successful schools?

This section looks at the results of the teacher survey and the conclusions drawn from the data. As this part of the study did not contain as large a dataset as that in the other parts, and did not yield as much significance through the chi-square tests that were described in section 5.3, I will draw on previous conclusions to offer possible explanations that fit with the argument that the way in which Hegartymaths is used does affect the efficacy of the platform in relation to students' GCSE performance. There are limitations to this argument, as well as questions surrounding the generalisability of these conclusions, that will be discussed in the final part of this section.

6.3.1 United Learning teacher survey conclusions

The findings of this survey are used to give possible explanations in relation to the research question *'How is Hegartymaths used in the most successful schools?'* The arguments here are solely based on the results described in section 5.3, which generated statistically significant results. The results of the survey that were statistically significant were gathered from the following questions:

Q12. How many tasks do you generally expect your students to complete when Hegartymaths is set as homework?
Q15. Are students directed to make notes while watching tutorial videos?
Q16. Do you use Hegartymaths to consolidate the learning of concepts that you are currently teaching?

It appears that the quantity of tasks a teacher expects pupils to complete when setting homework favours the schools which set 3 or more tasks as opposed to 1 or 2. This would result in the pupils becoming exposed to more topics through Hegartymaths, especially when it is taken into consideration that some teachers in the more successful schools who use Hegartymaths 'never' set Hegartymaths to consolidate the learning of concepts, and that all United Learning schools devote the same amount of time to learning mathematics.

By using Hegartymaths more often and by including topics that pupils have not learnt in class, the platform can be seen to be more effective in three separate ways. Firstly, as mentioned earlier, if pupils are learning more content through Hegartymaths in the more successful schools, they would have access to a greater amount of questions. Ultimately, this is associated with higher teacher expectations which will undoubtedly affect pupil performance positively. Secondly, it could be that pupils are covering the same amount of material, but that the teacher chooses to use more class time for pupils to learn through Hegartymaths. If this is the case, this would imply that class time is better spent by placing pupils in front of a machine rather than interacting with the teacher or their peers. Machine learning does offer the advantage that pupils can work at their own pace and can also be an effective tool for behaviour management in certain contexts. Having said that, this is unlikely as United Learning schools do not advocate a blended learning approach. Thirdly and finally, it could be that the teachers carefully choose which topics to teach the pupils solely through Hegartymaths, leaving more time for the teachers to focus on the other parts of the curriculum in class. It would be interesting to study this in more depth, especially as the findings discussed in sections 6.2.3 and 6.2.4 do seem to favour Hegartymaths for some types of questions and some areas of mathematics more than others.

A different approach to interpreting the above results would be that teachers directing pupils towards a greater amount of tasks are choosing quantity over quality, where the overall expectations of the amount of work they want pupils to do are the same, but the expectations of each of the 3 or more tasks is of a lesser quality. For example, the teacher could expect a lower minimum score if they are setting more quizzes, which is something future studies could explore. Alternatively, it could be interpreted as teacher preference in prioritising the quizzes over the video tutorials. A greater proportion of teachers in the most successful schools did not direct pupils to watch the video tutorials before attempting the quizzes (13%), as opposed to teachers in the least successful schools (7%). Even though these results did not generate statistical significance, there is merit in exploring this argument further, especially as the findings discussed in section 6.1.2.1 indicate that time spent on Hegartymaths is more effective on quizzes as opposed to videos.

Another reason to reject the 'quantity over quality' explanation as described above is the statistically significant findings observed when analysing whether teachers direct pupils to write notes while watching the video tutorials. The results described in section 5.3 indicate that it is advisable to direct pupils to make notes, as a greater proportion of teachers (90% as opposed to 71%) in more successful schools were seen to do this. This reinforces the argument that teachers of the more successful schools have higher expectations of how pupils use Hegartymaths. It further reinforces the belief that teaching pupils how to make high quality notes during the video tutorials is considered best practice, which is also what Colin Hegarty advocated when he visited the school I work at to train the maths department during the academic year 2016/17. A clear advantage of ensuring pupils are held to account for their notetaking is that they are more engaged with the entire video tutorial, as opposed to the specific part that they need to answer the question. Another recommended study would be to analyse the impact of notetaking further by examining the more successful pupils' notetaking habits and how their teacher has helped to shape this, so as to research and recommend what best practice is for using video tutorials in future.

6.3.2 United Learning teacher survey: Limitations and recommendations

As with all studies that use surveys, these are hard to justify in terms of validity and reliability (Gillham, 2000). It is far easier to justify the quasi-experiments and question-by-question analysis described earlier (Gorard, 2004). The purpose this survey has served in this study is to obtain relatively simple, closed facts about teachers' backgrounds and experiences, which surveys are known to be good for (Gorard, 2004), and use these in conjunction with the large data studies to provide possible explanations that would require further research if they are to be considered as trustworthy as the conclusions drawn from the rest of the study.

Chapter 7: Conclusion

This study is comprised of several analyses of data collected from across all mainstream secondary schools in England, with particular focus on 37 United Learning schools, to provide answers to the following research questions:

1) *To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE?*
2) *Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?*
3) *How is Hegartymaths used in the most successful schools?*

This study used a mixed-method approach, using both quantitative and qualitative data through the lens of post-positivism, encompassing an objectivist epistemological standpoint. In a climate where there have been calls for more rigorous research at the ground level so as to operationalise the existing and contemporary frameworks (Ruthven, 2014), and to use qualitative and quantitative data analyses simultaneously to harness the techniques of learning analytics and big data further (Hoyles and Noss, 2016), this study has contributed to the existing literature from a methodological point of view. I agree that there is a lot of scope for further quasi-experimental research using the analytics currently available. Educational researchers tend to favour a qualitative perspective as this lends itself more favourably to social research, but it can mean that the objective or quantitative viewpoint is often overlooked (e.g. Charmaz, 2008; McNiff and Whitehead, 2010).

Despite there being no evidence of original methods or methodology within this research, my claims to originality stem from the application of these existing methods and methodology. Through a post-positivist lens, I have been able to contribute my own interpretations of knowledge acquired through experience while collaborating with other practitioners who use Hegartymaths, as well as within my own classroom with the students I teach. This rigorous type of research at the ground level , which is scarce (Ruthven, 2014), coupled with the overlooked quantitative perspective (McNiff and Whitehead, 2010) forced me to seek original ways of applying the existing methodology using a mixed methods approach to handle the 'big data' that was available to me, which having access to also put me in a uniquely privileged position.

Calls for 'big data' have increased significantly across various fields, such as: healthcare (Wang, Kung and Byrd, 2018); insurance and construction (Dresner Advisory Services, 2017); e-commerce (Wu and Lin, 2018); telecommunication (Ahmed et al., 2018), which has become a matter of interest for researchers (Anshari, Alas and Yunus, 2019). Despite education being within the top five most active sectors in producing vast amounts of data (Dresner Advisory Services, 2017), a comprehensive review of 'big data' in this sector was still lacking until November 2020 (Baig, Shuib and Yadegaridehkordi, 2020). This review, which spans from January 2014 to April 2019, details 65 Primary studies, of which only 40 met the research protocols, and although 23% of these were quantitative studies and 3% mixed-methods, there were no studies that used quasi-experimental methods (or other) to assess the efficacy of an online platform for learning. A number of reasons can account for the lack of research of this nature, but arguably the most significant of those is the difficulty in processing, controlling or examining large datasets in a traditional way (Shahat, 2019). This offered me the opportunity to design a substantial part of the methodology using a unique approach, by freezing the 'big data' for carefully chosen moments in time, which allowed me to apply existing statistical analyses after amalgamating schools' data for comparisons to be made, while ensuring claims of validity were as high as possible.

The 'big data' available at teachers' fingertips is also very powerful as it provides an untapped opportunity to combine the quantitative aspect with their knowledge of the in-class dynamics to give insight through their interpretations through a post-positivist lens. Full workloads, paucity of digital literacy, limited grounding for research and a fear of data are just some of the hurdles that would need to be cleared, but I also call for more practitioners to be encouraged to engage with research of this nature at ground level. Throughout this research project, I gained invaluable experience and a range of vital insights, all of which contributed towards the design of the research, through: working with my own students using Hegartymaths; discussing the use of Hegartymaths with both expert and novice colleagues on a weekly basis; having regular contact with United Learning's National Director of Maths, who coordinates meetings with heads of department across the trust. In terms of design, for example, I then was careful to use language in my questionnaire that would make it accessible to teachers at all levels of proficiency and experience, such as Question 18. *Do you use Hegarty Maths by directing pupils to watch tutorials of concepts they haven't learnt in class yet?* This deliberately does not assume that the term 'flip learning' is known by the person answering, and therefore excludes any language that could be a barrier to completion of the questionnaire. Knowing first hand the struggles practitioners often face when teaching problem-solving techniques for AO3 questions, allowed me to give possible explanations as to why Hegartymaths is not as well suited to these problems. As a post-positivist who believes there is objective truth, but who accepts that we will not uncover this fully, the interpretations throughout this research are crucial and will offer, through a practitioner's eyes, an alternative viewpoint to that of a purely academic researcher.

This type of research has the potential to give teachers evidence of the value of technology in assessment (Donnelly et al., 2011), and empirical evidence of this nature suggesting better learning outcomes for students using technology could prompt practitioners and school leaders to invest in changing their current practices accordingly (Means, 2010). Hegartymaths' reach is exciting as it is vast enough to provide data for a large-scale national study, which would be highly unusual as research into more innovative technological pedagogy is predominantly small-scale. Seeking ways to process big data and use analytics such as those generated by Hegartymaths, by emulating well-defined data management strategies that have proven to be successful in large corporations (Bughin, 2016), could in theory recreate the entire results section of this thesis, year on year, within seconds (now that the methodology has been created), and similar systems can be created to help direct the right questions at class, department or school level, or even to generate accurate predictions that can influence decisions made by school leaders and policy makers. For example, this research reveals the positive and significant impact that Hegartymaths has on disadvantaged pupils. If similar projects assess other online platforms for other subjects, this could alert policy-makers to the potential this technology may have in closing the achievement gap between advantaged and disadvantaged pupils in this country. On a smaller scale, school leaders could do the same, by using the data to identify underperforming groups within their schools and then cascade this information to senior and middle leaders. Heads of Department should be directed to analyse the exam boards' breakdowns of the previous year's GCSE results, to direct their teachers to prioritise using Hegartymaths for specific topics and/or AOs that the prior GCSE cohort underperformed in.

The limitations and flaws of the research design, as described in that chapter, recommend ways that future studies of this nature could obtain more precise and reliable results, as well as pave the way for further studies of Hegartymaths - or other instructional video platforms - to be placed in context.

The findings of this study also contribute to the field of mathematics education research as this is the first time a large-scale study of Hegartymaths, which is used as a tool for mathematics teachers in approximately one third of mainstream secondary schools, has been conducted. These results also build on the existing literature concerning the use of technology in the mathematics classroom, particularly in the realm of instructional videos. By comparing the performance of schools that use Hegartymaths with schools that do not use this platform, which included almost the entire population of students in England, this fairly crude initial analysis did not provide conclusive results. Being the first research into Hegartymaths, it was still important to conduct this large-scale investigation to put the rest of the study in context. These inconclusive results do, however, indicate that Hegartymaths does show promise. The comparison between schools' prior data, overall performance, student make-up, and the measures used to determine progress in the mathematics element, favoured non-Hegartymaths schools, but this did not determine significant results for those schools. This was true to a larger extent when comparing the 37 United Learning schools who use Hegartymaths with the rest of the mainstream secondary schools in England, where the P8 measure of the mathematics element showed that these schools overturned the trend predicted by the prior data, which also favoured the non-United Learning schools. This was particularly true for students that were disadvantaged, where statistically significant gains in the P8 measure of the mathematics element were observed, despite the comparatively unfavourable prior data for the United Learning schools, once again.

The more sophisticated data analysis that concentrated on the 37 United Learning schools alone and included the amount of time spent on Hegartymaths, thereby assessing how usage affects performance, resulted in more fruitful findings. Here, comparing the performance of these schools based on the usage of Hegartymaths, I am able to conclude that the more time spent on Hegartymaths, the higher the performance in terms of attainment in mathematics on average for students who are disadvantaged and for pupils that had middle prior attainment, with 95% certainty for the pupils in the sample. The same could be said when analysing the progress of students, where not only can Hegartymaths be seen to be effective for disadvantaged students and pupils that have middle prior attainment, but statistically significant results were also seen when the pupils with high prior attainment were taken into consideration.

Further, time spent watching the video tutorials returned significant and positive results for the attainment measures of the mathematics element for some categories of pupils, namely the pupils that are disadvantaged and those with low prior attainment. However, no significant results were observed whilst considering the progress measures in mathematics, which is seen as a better measure of teaching as it takes account of pupils' prior data. When the same attainment and progress measures were correlated with the time spent by pupils on completing the quizzes, this was a very different case. Statistically significant and positive results were observed for both pupils that are disadvantaged and for those with middle prior attainment, in terms of both attainment and progress. Progress measures also indicated that the more time pupils spend on Hegartymaths, the more they improved for students of low prior attainment, and most notably of all, for all pupils in general. This allowed me to conclude, with 95% certainty for this sample, that time spent on Hegartymaths completing the quizzes affected pupil performance at GCSE, and that the time spent on quizzes contributed more to the performance overall than time spent on watching the video tutorials.

It is important to note here that these results could have profound impact on how education is configured in England. Policy makers, school leaders and classroom teachers are continuously striving to uncover tangible ways to reduce the disparity between the achievement of advantaged and disadvantaged children, and therefore to bring parity to these respective groups' life opportunities. OFSTED, rightly, scrutinises how educational establishments are working to reduce this gap, and this research project goes some way to providing the beginnings of a meaningful, practical solution that can be implemented with relative ease.

The question-by-question analysis, where the average score for each question on the GCSE Summer 2019 series was correlated with the overall time spent on the most relevant Hegartymaths topics for each of the associated exam questions, did not provide any insight into whether the efficacy of Hegartymaths is different, depending on the exam board (AQA or Edexcel), tier of entry or if the paper permitted the use of a calculator or not. This analysis does suggest that Hegartymaths is more suited to questions examining AO1, than AO2 and AO3, although it was only AO3 items that did not yield any positive and significant results. This underpinned the argument that Hegartymaths was also seen to be more effective for questions assessing pupils' mathematics in the areas of Algebra, Geometry, Number and Statistics, where the questions seen in the exam that generated positive and significant results were more aligned to examining pupils' procedural knowledge as opposed to their conceptual understanding of these topics. A deeper analysis showed that Algebra is the topic I am most certain is aligned to Hegartymaths, which bodes well for enhancing the students' overall performance in their GCSE if AQA and Edexcel continue to award more marks for Algebra than any other areas of mathematics.

The question-by-question analysis also suggests that that some of the 37 United Learning schools were more successful than others in their use of Hegartymaths. This prompted me to look to identify the differences between the schools, and how that might impact on their students' success; this was achieved through surveying United Learning teachers of mathematics. It appears that a positive impact on GCSE outcomes is generated by the following practices in some schools: setting 3 or more Hegartymaths tasks at a time; allowing some topics or parts of topics to be taught solely through Hegartymaths; directing pupils to write notes when watching the tutorials.

As well as the contribution these findings make to the existing - although limited - literature on using video tutorials for a blended learning approach in mathematics (Hampton, 2014; Bray and Tangney, 2017; McCulloch et al., 2018), I hope that the findings of this study will provide some guidance to teachers of mathematics. As a current practitioner myself, I shall be using these to revise my decisions on which Hegartymaths clips to use, when to direct pupils to make notes while watching the video, and when to direct my pupils to solely complete the quizzes in future. This would be particularly helpful if a similar situation arises wherein schools are once again shut down due to the coronavirus pandemic.

Aside from the recommendations for future research that were put forward in the discussion chapter, there have been several recent Hegartymaths developments that were not available for research at the time of writing. Firstly, 'Fix up 5', enables students to access five questions they had previously got incorrect. Providing students with a quick and easy way to select and practise questions that were beyond their capabilities (at least initially) is an attempt by Hegartymaths to tap into the research of deliberate practice (Ericsson, 2016), as opposed to drill-and-practise. It would be interesting to see how the analytics of 'Fix up 5' correlate with student performance at GCSE and, further, with the findings of this study.

Another feature recently created on Hegartymaths is called MemRi and was introduced to teachers to use with their pupils in 2019. Conventionally, Hegartymaths arranges its video tutorials by topic and questions for only that topic are found in the associated quizzes; this is known as blocked practice. Inspired by research into spaced or distributed practice that purports that this promotes better learning outcomes for students than blocked practice, (Cepeda et al., 2008; Rohrer, 2015; Dunlosky et al., 2013) as well as interleaved practice (Rohrer and Taylor, 2007; Kornell and Bjork, 2008; Guzman-Munoz, 2017), MemRi uses algorithms that interleave bespoke questions in a spaced way by using the previous work pupils have completed on Hegartymaths, so as to promote learning for every individual according to their needs. The time pupils spend on MemRi would also have been an interesting avenue to explore, to see the extent it supports student performance in the mathematics GCSE.

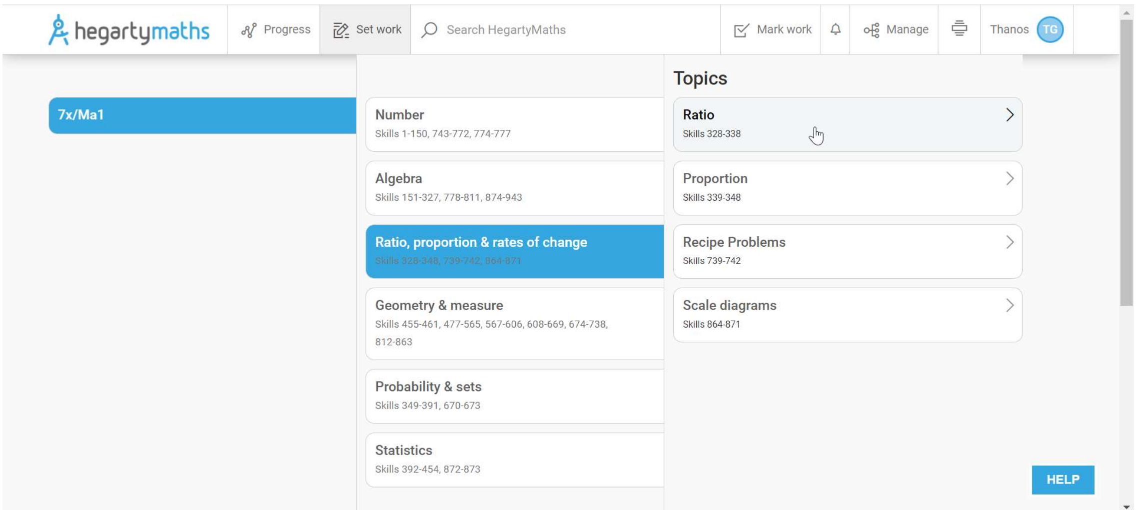
At the time of writing, this is the first study into the efficacy of Hegartymaths, despite it being used by approximately one third of the mainstream secondary schools in England. It would not have achieved such a reach if the potential it has in terms of teaching and learning for teachers and students of mathematics was not recognised by schools: the quizzes, which are automatically marked, reduce teacher workload; the analytics equip teachers with the capacity to instil a growth mindset in their pupils by celebrating work ethic when displaying the amount of hours students spent on the platform; the instant feedback for pupils and further, the fact that knowing if they are correct or not reduces the amount of students continuing to practise incorrectly; the mapping of the curriculum allows pupils to readily access the building blocks of learning required to attempt the quizzes; setting bespoke work for pupils to enable them to catch up on work missed; the video tutorial explanations can be used by many teachers for continual professional development. The clear advantages to using Hegartymaths are manifold. Personally, I see the benefits of the platform, and believe that most mathematics departments who have implemented it would now find it hard to go without it and that, unless something superior is created to take its place, Hegartymaths is here to stay.

As with all teaching tools however, the disadvantages are also clear. The platform was designed to work alongside the teacher, but if used incorrectly teachers who become over-reliant on the online resource can become stifled in their development as teachers. By always defaulting to Hegartymaths to deliver new content to pupils, teachers lose vital opportunities to plan instructional sequences for their classes that would include careful modelling, planning questions, pre-empting pupil misconceptions and being highly responsive to students. Further, my personal belief is that the central downside to Hegartymaths is that a teacher can be misled into thinking that a pupil who scores 100% on a particular quiz then possesses the conceptual knowledge for that topic. This threat is also present in any examination that does not test for conceptual knowledge. However, even as a teacher who takes a constructivist approach to knowledge acquisition and strives to teach mathematics for mathematics' sake and not for an exam, where the teacher's role prioritises asking questions over giving answers, I encounter the same moral dilemma every year: do I continue to uphold my belief that mathematics should be taught in such a way that new content is framed as high challenge problems that groups strive to solve collaboratively, but in so doing I run the risk of jeopardising my pupils' chances in an exam setting. Should I alter my teaching to ensure that all topics are covered in a less conceptual way in order to maximise my pupils' outcomes at GCSE, which ultimately creates more opportunities for these young people and is therefore also a central reason as to why I teach. Although more research into how we should best use Hegartymaths is something I call for, I believe the platform has the genuine potential to help me with my dilemma. By investigating further how best to implement Hegartymaths in the classroom, certain ways in which the platform can effectively replace the teacher could be identified, thereby leaving more time for practitioners to hone their teaching of conceptual mathematics. In doing so, pupil outcomes are improved while still ensuring that their students are equipped with fundamental procedural mathematical knowledge.

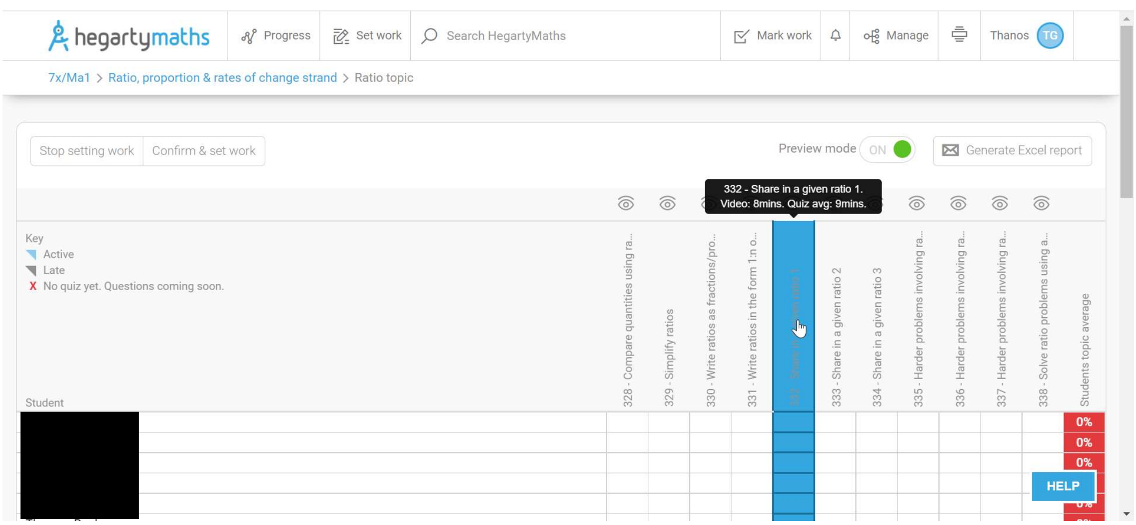
Appendices

Appendix A: Description of Hegartymaths

The original online platform Hegartymaths, whose inception was as a free website launched in 2013, was used in over two hundred worldwide territories and had over six million views (https://hegartymaths.com/story). At that point the website was a collection of video tutorials, inspired by Khan Academy, that pupils could use to revise what they had learned in-class and to help students who may have missed lessons. It underwent a relaunch in 2016, whereby the platform grew in scope to cover a variety of topics and, at the time of writing, there were around 900 video tutorials with accompanying quizzes. The teacher is able to set work, with ease, for a class or on an individual basis as follows:

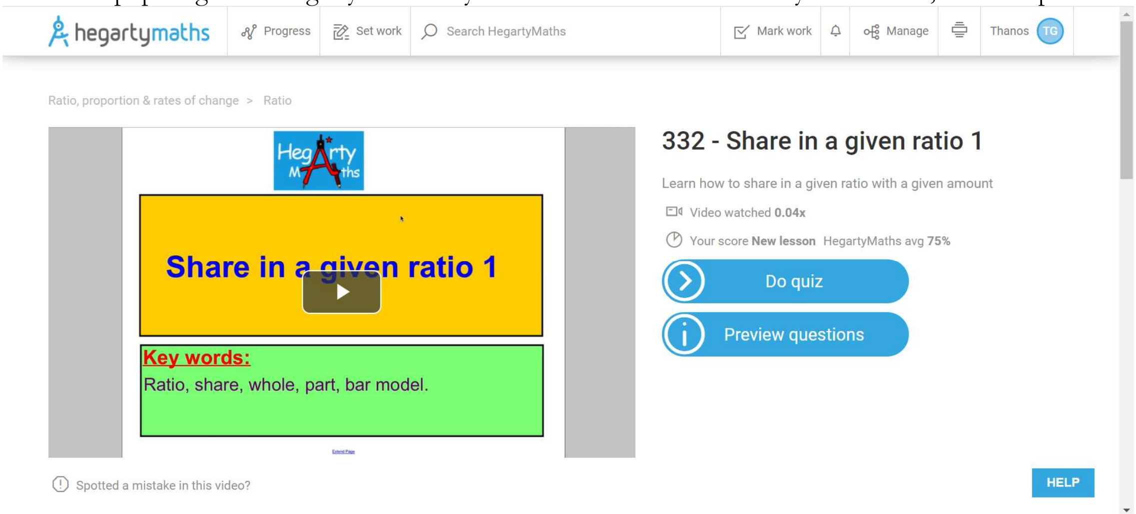


The screenshot above shows how the topics are arranged, and below shows how a teacher would assign topics to pupils:

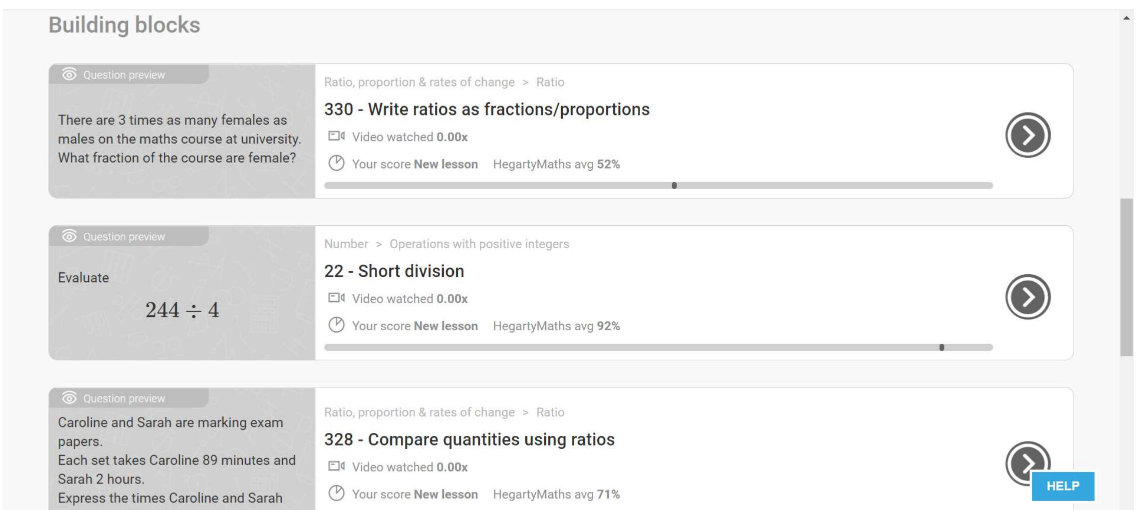


Once a teacher has selected the specific clips and quizzes they want the class or individual to work on, they can specify when they expect the work to be due and add any further instructions for the students. The website advises that pupils take notes during the video tutorials, before completing a scaffolded quiz that matches the exact content from a particular video. The alignment between the quiz and the video creates conditions for pupils to score highly when they engage well with the video. Pupil scores automatically update in the teacher's markbook.

When the pupil logs into Hegartymaths they are directed to the work set by the teacher, for example:

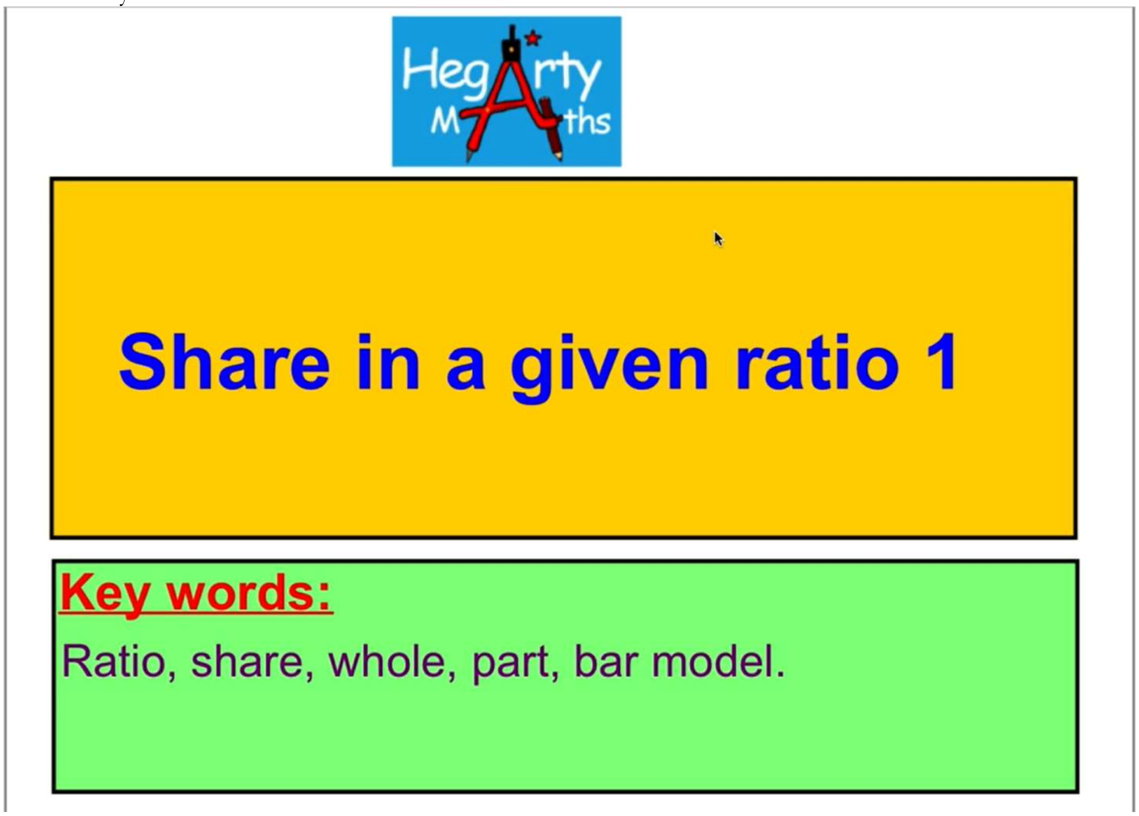


First, they can click to watch the video and then click to do the quiz. The screenshot below shows the 'building blocks', which students are encouraged to click on if they are struggling to access the work set by the teacher. This then directs them to another video and quiz, which is deemed as pre-requisite knowledge needed to access the task set by the teacher.

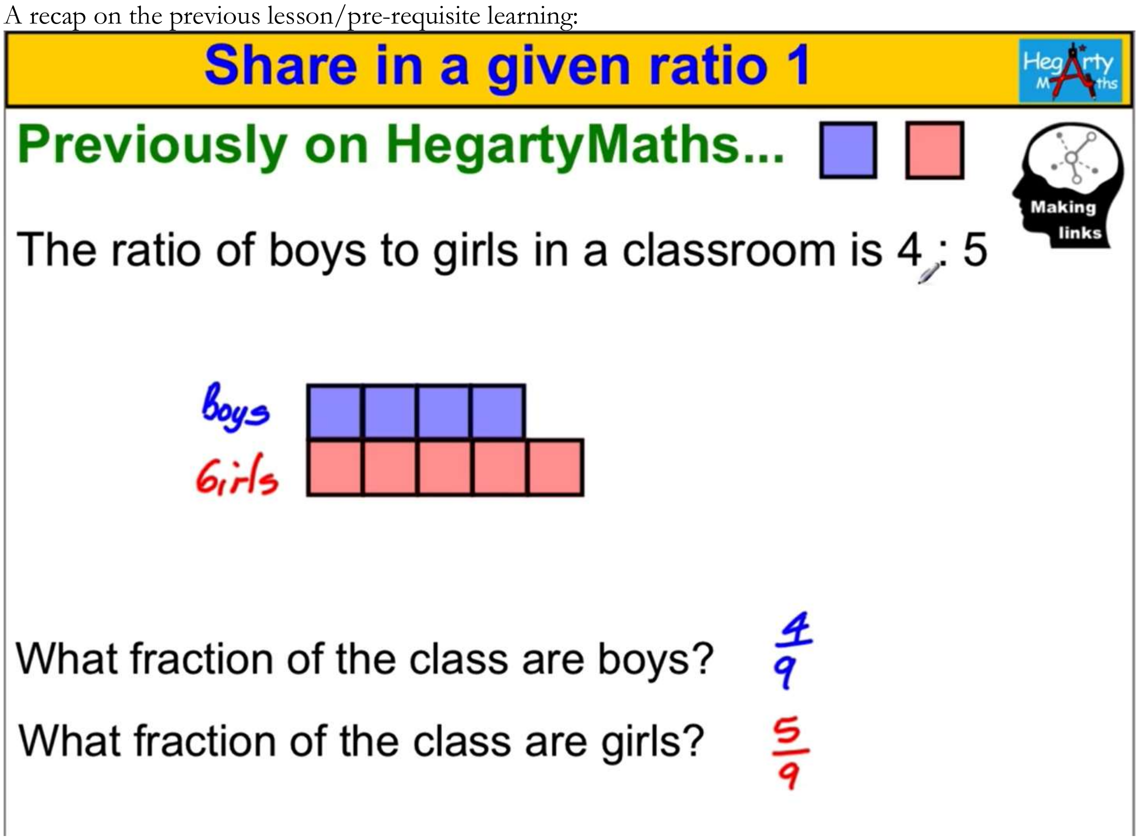


All the videos include:

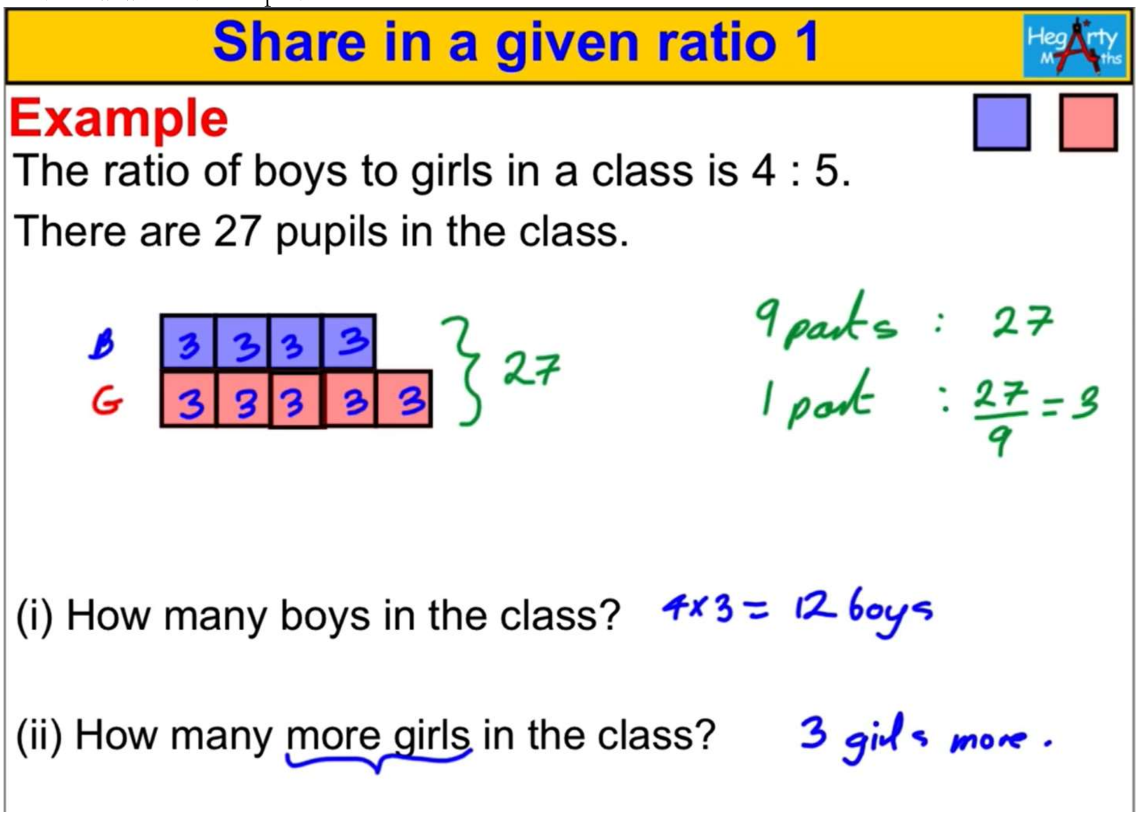
Title & Key words:



A recap on the previous lesson/pre-requisite learning:

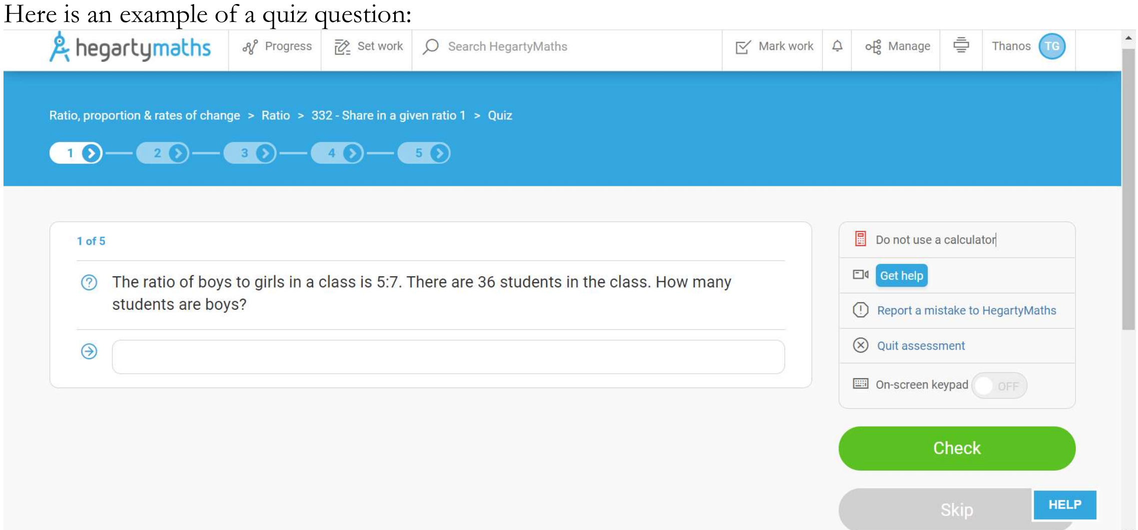


And a few worked examples:

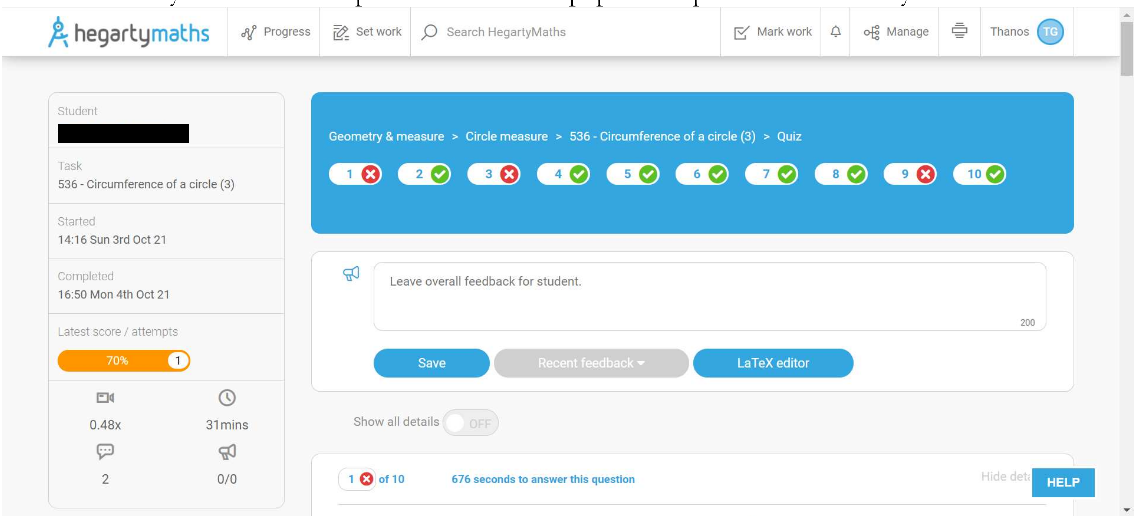


The quizzes have varying amounts of questions according to the topic, and feature an on-screen keypad which allows easy input of mathematical language and a calculator (if allowed) to allow pupils to check whether they may have made a mistake. Pupils receive the same amount of questions in the same format for the majority of the clips, but the numbers are different.

Here is an example of a quiz question:



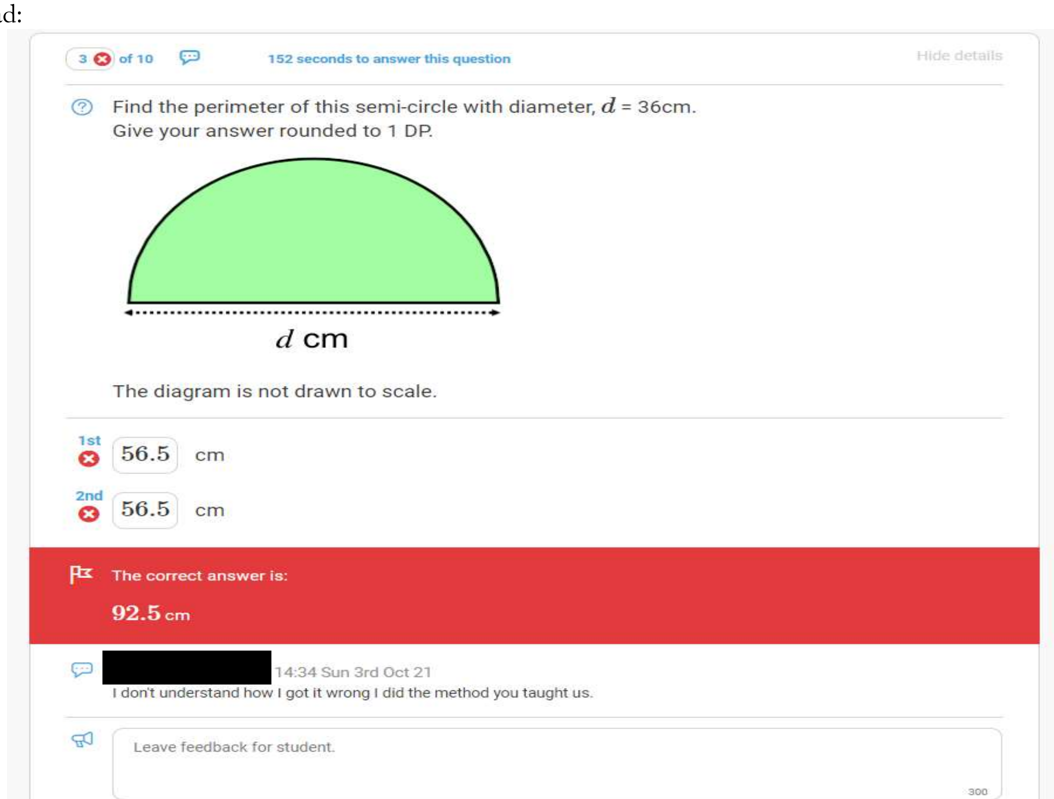
There is a wealth of analytics at the teacher's fingertips at school, class and individual pupil level. At the individual level you can view the performance of the pupil on a specific skill that they worked on:



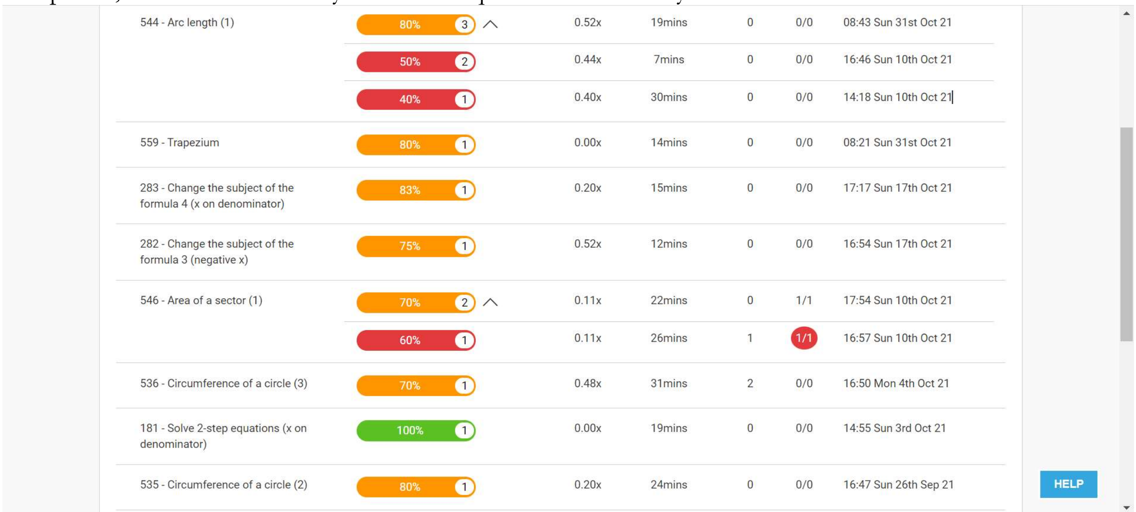
The above screenshot details:

1) The day and time the pupil started and finished the task;
2) Their score as a percentage;
3) How much of the video tutorial they decided to watch;
4) The total time the pupil took to complete the quiz;
5) The amount of comments made by the student;
6) Which questions they answered correctly and incorrectly;
7) How long it took for the pupil to answer each question.

If you scroll further down you can also see the answers pupils gave both for their first and second attempts for the questions they struggled with, as well as any comments they made for their teacher to read:



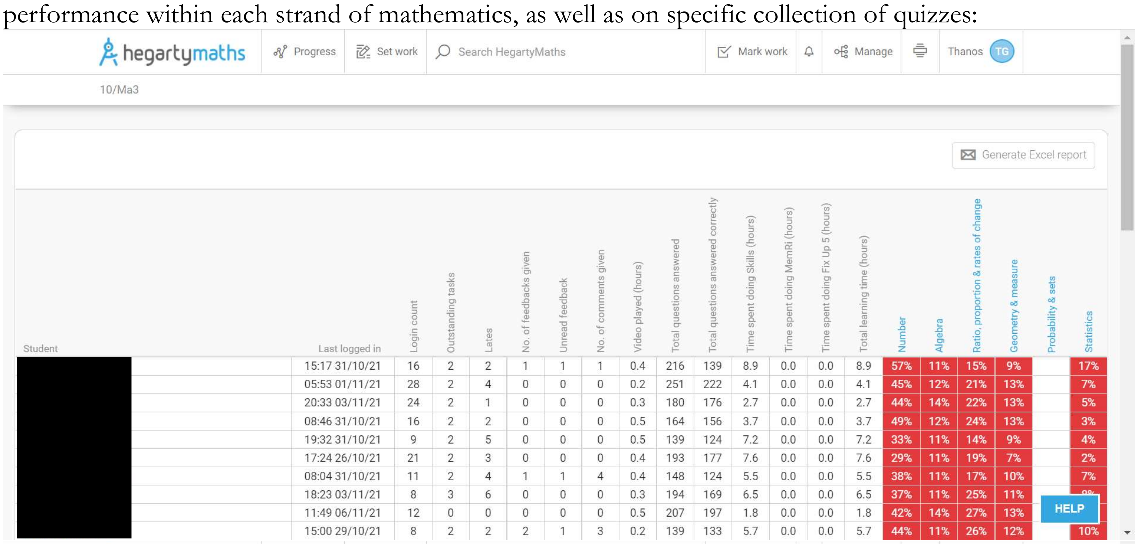
Also, on an individual basis, both the teacher and pupil can access a summary of all the tasks the pupil has completed, and the student may re-take the quiz as often as they like:



544 - Arc length (1)	80%	3	0.52x	19mins	0	0/0	08:43 Sun 31st Oct 21
	50%	2	0.44x	7mins	0	0/0	16:46 Sun 10th Oct 21
	40%	1	0.40x	30mins	0	0/0	14:18 Sun 10th Oct 21
559 - Trapezium	80%	1	0.00x	14mins	0	0/0	08:21 Sun 31st Oct 21
283 - Change the subject of the formula 4 (x on denominator)	83%	1	0.20x	15mins	0	0/0	17:17 Sun 17th Oct 21
282 - Change the subject of the formula 3 (negative x)	75%	1	0.52x	12mins	0	0/0	16:54 Sun 17th Oct 21
546 - Area of a sector (1)	70%	2	0.11x	22mins	0	1/1	17:54 Sun 10th Oct 21
	60%	1	0.11x	26mins	1	1/1	16:57 Sun 10th Oct 21
536 - Circumference of a circle (3)	70%	1	0.48x	31mins	2	0/0	16:50 Mon 4th Oct 21
181 - Solve 2-step equations (x on denominator)	100%	1	0.00x	19mins	0	0/0	14:55 Sun 3rd Oct 21
535 - Circumference of a circle (2)	80%	1	0.20x	24mins	0	0/0	16:47 Sun 26th Sep 21

HELP

The individual pupils' statistics are collated together per class, so the teacher can see the overall pupil performance within each strand of mathematics, as well as on specific collection of quizzes:



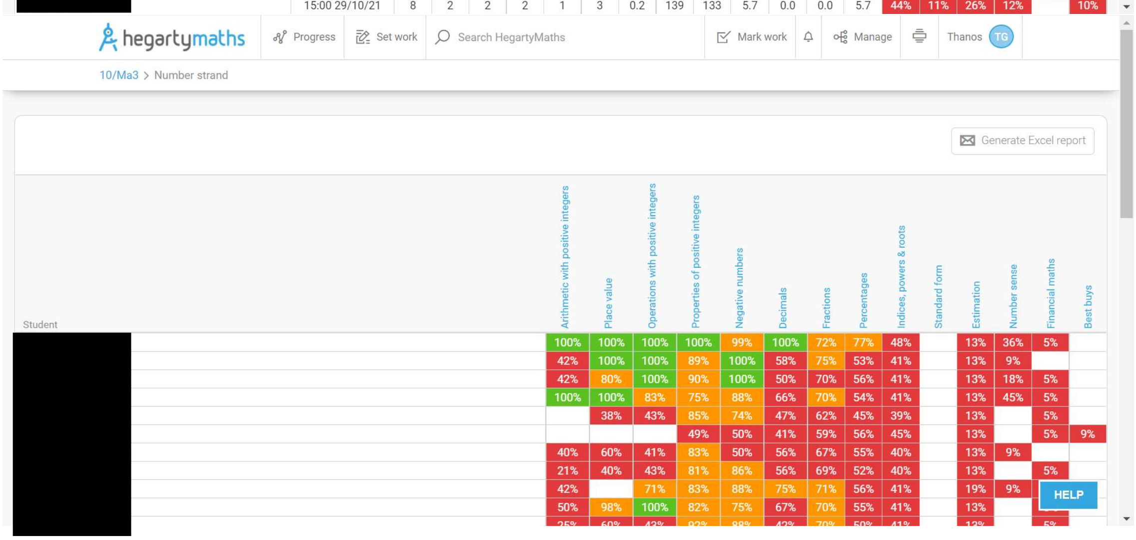
hegartymaths | Progress | Set work | Search HegartyMaths | Mark work | Manage | Thanos TG

10/Ma3

Generate Excel report

Student	Last logged in	Login count	Outstanding tasks	Lates	No. of feedbacks given	Unread feedback	No. of comments given	Video played (hours)	Total questions answered	Total questions answered correctly	Time spent doing Skills (hours)	Time spent doing MemRi (hours)	Time spent doing Fix Up 5 (hours)	Total learning time (hours)	Number	Algebra	Ratio, proportion & rates of change	Geometry & measure	Probability & sets	Statistics
[redacted]	15:17 31/10/21	16	2	2	1	1	1	0.4	216	139	8.9	0.0	0.0	8.9	57%	11%	15%	9%		17%
[redacted]	05:53 01/11/21	28	2	4	0	0	0	0.2	251	222	4.1	0.0	0.0	4.1	45%	12%	21%	13%		7%
[redacted]	20:33 03/11/21	24	2	1	0	0	0	0.3	180	176	2.7	0.0	0.0	2.7	44%	14%	22%	13%		5%
[redacted]	08:46 31/10/21	16	2	2	0	0	0	0.5	164	156	3.7	0.0	0.0	3.7	49%	12%	24%	13%		3%
[redacted]	19:32 31/10/21	9	2	5	0	0	0	0.5	139	124	7.2	0.0	0.0	7.2	33%	11%	14%	9%		4%
[redacted]	17:24 26/10/21	21	2	3	0	0	0	0.4	193	177	7.6	0.0	0.0	7.6	29%	11%	19%	7%		2%
[redacted]	08:04 31/10/21	11	2	4	1	1	4	0.4	148	124	5.5	0.0	0.0	5.5	38%	11%	17%	10%		7%
[redacted]	18:23 03/11/21	8	3	6	0	0	0	0.3	194	169	6.5	0.0	0.0	6.5	37%	11%	25%	11%		[illegible]
[redacted]	11:49 06/11/21	12	0	0	0	0	0	0.5	207	197	1.8	0.0	0.0	1.8	42%	14%	27%	13%	[illegible]	[illegible]
[redacted]	15:00 29/10/21	8	2	2	2	1	3	0.2	139	133	5.7	0.0	0.0	5.7	44%	11%	26%	12%		10%

HELP



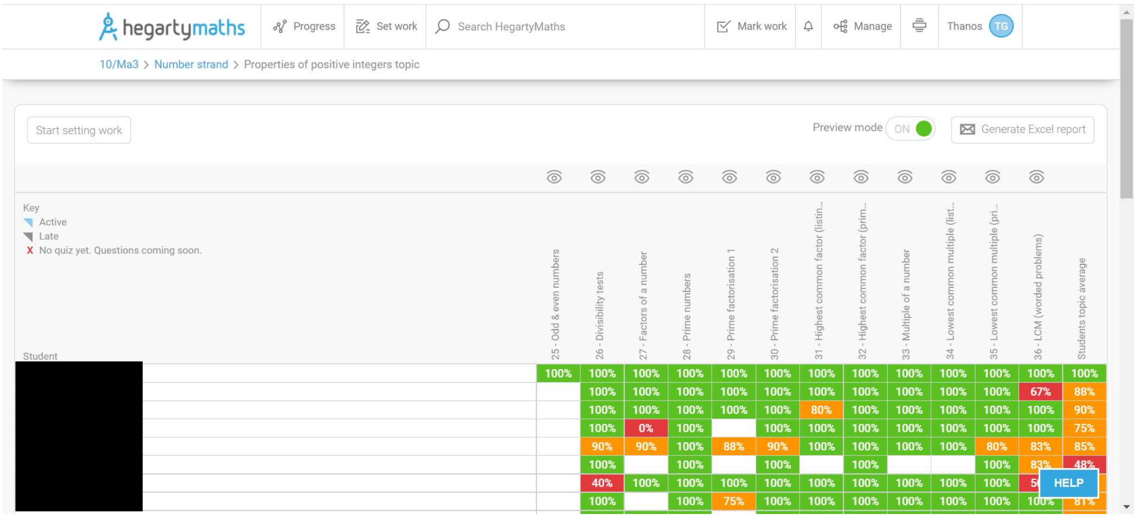
hegartymaths | Progress | Set work | Search HegartyMaths | Mark work | Manage | Thanos TG

10/Ma3 > Number strand

Generate Excel report

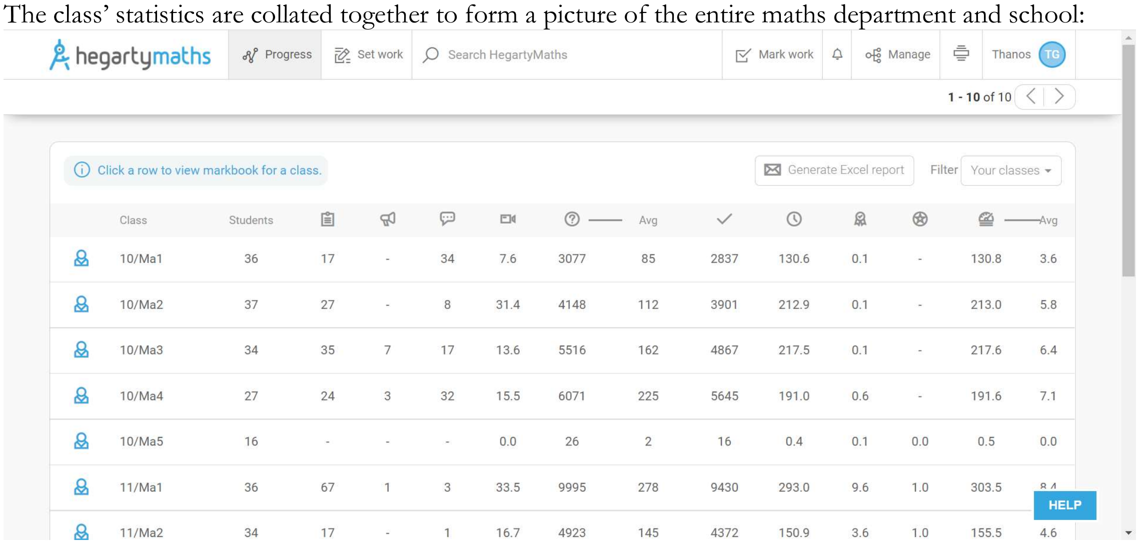
Student	Arithmetic with positive integers	Place value	Operations with positive integers	Properties of positive integers	Negative numbers	Decimals	Fractions	Percentages	Indices, powers & roots	Standard form	Estimation	Number sense	Financial maths	Best buys
[redacted]	100%	100%	100%	100%	99%	100%	72%	77%	48%		13%	36%	5%	
[redacted]	42%	100%	100%	89%	100%	58%	75%	53%	41%		13%	9%		
[redacted]	42%	80%	100%	90%	100%	50%	70%	56%	41%		13%	18%	5%	
[redacted]	100%	100%	83%	75%	88%	66%	70%	54%	41%		13%	45%	5%	
[redacted]		38%	43%	85%	74%	47%	62%	45%	39%		13%		5%	
[redacted]				49%	50%	41%	59%	56%	45%		13%		5%	9%
[redacted]	40%	60%	41%	83%	50%	56%	67%	55%	40%		13%	9%		
[redacted]	21%	40%	43%	81%	86%	56%	69%	52%	40%		13%		5%	
[redacted]	42%		71%	83%	88%	75%	71%	56%	41%		19%	9%	[illegible]	[illegible]
[redacted]	50%	98%	100%	82%	75%	67%	70%	55%	41%		13%		[illegible]	[illegible]

HELP



Student	25 - Odd & even numbers	26 - Divisibility tests	27 - Factors of a number	28 - Prime numbers	29 - Prime factorisation 1	30 - Prime factorisation 2	31 - Highest common factor (listin...	32 - Highest common factor (prim...	33 - Multiple of a number	34 - Lowest common multiple (list...	35 - Lowest common multiple (pri...	36 - LCM (worded problems)	Students topic average
[redacted]	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	67%	88%
		100%	100%	100%	100%	100%	80%	100%	100%	100%	100%	100%	90%
		100%	0%	100%		100%	100%	100%	100%	100%	100%	100%	75%
		90%	90%	100%	88%	90%	100%	100%	100%	100%	80%	83%	85%
		100%		100%		100%		100%			100%	83%	48%
		40%	100%	100%	100%	100%	100%	100%	100%	100%	100%	[illegible]	[illegible]
		100%		100%	75%	100%	100%	100%	100%	100%	100%	100%	81%

The class' statistics are collated together to form a picture of the entire maths department and school:



Class	Students						Avg						Avg
10/Ma1	36	17	-	34	7.6	3077	85	2837	130.6	0.1	-	130.8	3.6
10/Ma2	37	27	-	8	31.4	4148	112	3901	212.9	0.1	-	213.0	5.8
10/Ma3	34	35	7	17	13.6	5516	162	4867	217.5	0.1	-	217.6	6.4
10/Ma4	27	24	3	32	15.5	6071	225	5645	191.0	0.6	-	191.6	7.1
10/Ma5	16	-	-	-	0.0	26	2	16	0.4	0.1	0.0	0.5	0.0
11/Ma1	36	67	1	3	33.5	9995	278	9430	293.0	9.6	1.0	303.5	8.4
11/Ma2	34	17	-	1	16.7	4923	145	4372	150.9	3.6	1.0	155.5	4.6

The icons at the top inform the teacher of the following:

	Number of tasks set (since the start of the academic year)
	Number of feedback comments given (by the teacher to the pupil online)
	Number of comments given (by the pupil to the teacher online)
	The number of hours a pupil has played video tutorials
	Total questions answered by the pupils in the class
Avg	The average number of questions answered by a pupil in the class
	Total questions answered correctly by the pupils in the class
	Total time spent on answering the clip quizzes (in hours)

	Total time spent on answering 'MemRi' questions (in hours) by the pupils in the class
	Total time spent on answering 'Fix Up 5' questions (in hours) by the pupils in the class
	Total learning time on Hegartymaths (in hours) by the pupils in the class
Avg	The average learning time spent on Hegartymaths by a pupil in the class

Appendix B: Gov.uk data provided for all schools in England

https://www.compare-school-performance.service.gov.uk/schools-by-type?step=phase&geographic=all&region=0&phase=secondary

Column	Metafile heading	Metafile description
1	RECTYPE	Record type (1=mainstream school; 2=special school; 4=local authority; 5=National (all schools); 7=National (maintained schools))
2	LEA	Local authority code (see separate list of local authorities and their codes)
3	ESTAB	Establishment number
4	URN	School Unique Reference Number
5	SCHNAME	School name
6	SCHNAME_AC	School now known as (used if the school has converted to an academy on or after 12 Sept 2018)
7	ADDRESS1	School address (1)
8	ADDRESS2	School address (2)
9	ADDRESS3	School address (3)
10	TOWN	School town
11	PCODE	School postcode
12	TELNUM	School telephone number
13	CONTFLAG	Contingency flag – school results 'significantly affected'. This field is zero for all schools.
14	ICLOSE	Closed school flag (0=open; 1=closed)
15	NFTYPE	School type (see separate list of abbreviations used in the tables)
16	RELDENOM	School religious character
17	ADMPOL	School admissions policy (self-declared by schools on Edubase)
18	ADMPOL_18	School admissions policy – new definition from 2018
19	EGENDER	School gender of entry

20	FEEDER	Indicates whether school is a feeder school for sixth form centre/consortia (0=No; 1=Yes)
21	TABKS2	Indicates whether school is published in the primary school (key stage 2) performance tables (0=No; 1=Yes)
22	TAB1618	Indicates whether school is published in the school and college (16-18) performance tables (0=No; 1=Yes)
23	AGERANGE	Age range
24	CONFEXAM	Indicates whether the school has checked its results (R=No; blank=Yes)
25	TOTPUPS	Number of pupils on roll (all ages)
26	NUMBOYS	Total boys on roll (including part-time pupils)
27	NUMGIRLS	Total girls on roll (including part-time pupils)
28	TPUP	Number of pupils at the end of key stage 4
29	BPUP	Number of boys at the end of key stage 4
30	PBPUP	Percentage of pupils at the end of key stage 4 who are boys
31	GPUP	Number of girls at the end of key stage 4
32	PGPUP	Percentage of pupils at the end key stage 4 who are girls
33	KS2APS	Key stage 2 Average Points Score of the cohort at the end of key stage 4
34	TPRIORLO	Number of pupils at the end of key stage 4 with low prior attainment at the end of key stage 2
35	PTPRIORLO	Percentage of pupils at the end of key stage 4 with low prior

		attainment at the end of key stage 2
36	TPRIORAV	Number of pupils at the end of key stage 4 with middle prior attainment at the end of key stage 2
37	PTPRIORAV	Percentage of pupils at the end of key stage 4 with middle prior attainment at the end of key stage 2
38	TPRIORHI	Number of pupils at the end of key stage 4 with high prior attainment at the end of key stage 2
39	PTPRIORHI	Percentage of pupils at the end of key stage 4 with high prior attainment at the end of key stage 2
40	TFSM6CLA1A	Number of disadvantaged pupils at the end of key stage 4
41	PTFSM6CLA1A	Percentage of pupils at the end of key stage 4 who are disadvantaged
42	TNOTFSM6CLA1A	Number of non-disadvantaged pupils at the end of key stage 4
43	PTNOTFSM6CLA1A	Percentage of pupils at the end of key stage 4 who are not disadvantaged
44	TEALGRP2	Number of pupils at the end of key stage 4 with English as additional language (EAL)
45	PTEALGRP2	Percentage of pupils at the end of key stage 4 with English as additional language (EAL)
46	TEALGRP1	Number of pupils at the end of key stage 4 with English as their first language
47	PTEALGRP1	Percentage of pupils at the end of key stage 4 with English as their first language

48	TEALGRP3	Number of pupils at the end of key stage 4 whose first language is unclassified
49	PTEALGRP3	Percentage of pupils at the end of key stage 4 whose first language is unclassified
50	TNMOB	Number of pupils at the end of key stage 4 who are non-mobile
51	PTNMOB	Percentage of pupils at the end of key stage 4 who are non-mobile
52	SENSE4	Number of pupils at the end of key stage 4 with special educational needs (SEN) with a statement or Education, health and care (EHC) plan
53	PSENSE4	Percentage of pupils at the end of key stage 4 with special educational needs (SEN) with a statement or Education, health and care (EHC) plan
54	SENAPK4	Number of pupils at the end of key stage 4 with special educational needs (SEN) without a statement or Education, health and care (EHC) plan
55	PSENAPK4	Percentage of pupils at the end of key stage 4 with special educational needs (SEN) without a statement or Education, health and care (EHC) plan
56	SEN_ALL	Number of pupils at the end of key stage 4 with special educational needs (SEN) including those with or without a statement or Education, health and care (EHC) plan
57	PSEN_ALL	Percentage of pupils at the end of key stage 4 with special educational needs (SEN)

		including those with or without a statement or Education, health and care (EHC) plan
58	TOTATT8	Total sum of Attainment 8 scores
59	ATT8SCR	Average Attainment 8 score per pupil
60	TOTATT8ENG	Total sum of Attainment 8 scores for English element
61	ATT8SCRENG	Average Attainment 8 score per pupil for English element
62	TOTATT8MAT	Total sum of Attainment 8 scores for mathematics element
63	ATT8SCRMAT	Average Attainment 8 score per pupil for mathematics element
64	TOTATT8EBAC	Total sum of Attainment 8 scores for EBacc element
65	ATT8SCREBAC	Average Attainment 8 score per pupil for EBacc element
66	TOTATT8OPEN	Total sum of Attainment 8 scores for open element
67	ATT8SCROPEN	Average Attainment 8 score per pupil for open element
68	TOTATT8OPENG	Total sum of Attainment 8 scores for open element – GCSE only
69	ATT8SCROPENG	Average Attainment 8 score per pupil for open element – GCSE only
70	TOTATT8OPENNG	Total sum of Attainment 8 scores for open element – non-GCSE only
71	ATT8SCROPENNG	Average Attainment 8 score per pupil for open element – non-GCSE only
72	AVGEBACFILL	Average number of EBacc slots filled in Attainment 8 per pupil
73	AVGOPENFILL	Average number of Open slots filled in Attainment 8 per pupil
74	P8PUP	Number of pupils included in Progress 8 measure

75	TP8ADJ	Number of pupils who have had P8 score adjusted in average
76	P8MEACOV	Percentage of pupils at the end of key stage 4 included in Progress 8 measure
77	P8MEA	Progress 8 measure after adjustment for extreme scores
78	P8CILOW	Progress 8 lower 95% confidence interval for adjusted average
79	P8CIUPP	Progress 8 upper 95% confidence interval for adjusted average
80	P8MEA_ORIG	Progress 8 measure based on unadjusted pupil scores
81	P8CILOW_ORIG	Progress 8 lower 95% confidence interval for unadjusted average
82	P8CIUPP_ORIG	Progress 8 upper 95% confidence interval for unadjusted average
83	P8MEAENG	Progress 8 measure for English element
84	P8MEAENG_CILOW	Lower 95% confidence interval for Progress 8 English element
85	P8MEAENG_CIUPP	Upper 95% confidence interval for Progress 8 English element
86	P8MEAMAT	Progress 8 measure for mathematics element
87	P8MEAMAT_CILOW	Lower 95% confidence interval for Progress 8 maths element
88	P8MEAMAT_CIUPP	Upper 95% confidence interval for Progress 8 maths element
89	P8MEAEBAC	Progress 8 measure for EBacc element
90	P8MEAEBAC_CILOW	Lower 95% confidence interval for Progress 8 EBacc element
91	P8MEAEBAC_CIUPP	Upper 95% confidence interval for Progress 8 EBacc element
92	P8MEAOPEN	Progress 8 measure for open element
93	P8MEAOPEN_CILOW	Lower 95% confidence interval for Progress 8 open element

94	P8MEAOPEN_CIUPP	Upper 95% confidence interval for Progress 8 open element
95	PTL2BASICS_94	% of pupils achieving standard 9-4 passes in both English and mathematics GCSEs
96	PTL2BASICS_95	% of pupils achieving strong 9-5 passes in both English and mathematics GCSEs
97	TOTEBACCAPS	Total EBacc APS score per pupil
98	EBACCAPS	Average EBacc APS score per pupil
99	EBACCAPS_FSM6CLA1A	Average EBacc APS score per disadvantaged pupil
100	EBACCAPS_NFSM6CLA1A	Average EBacc APS score per non-disadvantaged pupil
101	EBACCAPS_LO	Average EBacc APS score per pupil with low prior attainment
102	EBACCAPS_AV	Average EBacc APS score per pupil with middle prior attainment
103	EBACCAPS_HI	Average EBacc APS score per pupil with high prior attainment
104	EBACCAPS_EAL	Average EBacc APS score per pupil for whom English is an additional language
105	EBACCAPS_GIRLS	Average EBacc APS score per girl
106	EBACCAPS_BOYS	Average EBacc APS score per boy
107	EBACCAPS_NMOB	Average EBacc APS score per non-mobile pupil
108	EBACCAPS_18	Average EBacc APS score per pupil in 2018
109	EBACCAPS_FSM6CLA1A_18	Average EBacc APS score per disadvantaged pupil in 2018
110	EBACCAPS_NFSM6CLA1A_18	Average EBacc APS score per non-disadvantaged pupil in 2018
111	TEBACC_E_PTQ_EE	Number of key stage 4 pupils with entries in all English Baccalaureate subject areas

112	PTEBACC_E_PTQ_EE	Percentage of key stage 4 pupils with entries in all English Baccalaureate subject areas
113	PTEBACC_94	Percentage of pupils achieving the English Baccalaureate with 9-4 passes
114	PTEBACC_95	Percentage of pupils achieving the English Baccalaureate with 9-5 passes
115	TEBACENG_E_PTQ_EE	Number of pupils entering the English Baccalaureate English subject area
116	PTEBACENG_E_PTQ_EE	Percentage of pupils entering the English Baccalaureate English subject area
117	TEBACMAT_E_PTQ_EE	Number of pupils entering the English Baccalaureate Maths subject area
118	PTEBACMAT_E_PTQ_EE	Percentage of pupils entering the English Baccalaureate Maths subject area
119	TEBAC2SCI_E_PTQ_EE	Number of pupils entering the English Baccalaureate Science subject area
120	PTEBAC2SCI_E_PTQ_EE	% of pupils entering the English Baccalaureate Science subject area
121	TEBACHUM_E_PTQ_EE	Number of pupils entering the English Baccalaureate Humanities subject area
122	PTEBACHUM_E_PTQ_EE	% of pupils entering the English Baccalaureate Humanities subject area
123	TEBACLAN_E_PTQ_EE	Number of pupils entering the English Baccalaureate Language subject area
124	PTEBACLAN_E_PTQ_EE	% of pupils entering the English Baccalaureate Language subject area

125	PTEBACENG_94	% of pupils achieving the EBacc English subject area with a standard 9-4 pass
126	PTEBACENG_95	% of pupils achieving the EBacc English subject area with a strong 9-5 pass
127	PTEBACMAT_94	% of pupils achieving the EBacc Maths subject area with a standard 9-4 pass
128	PTEBACMAT_95	% of pupils achieving the EBacc Maths subject area with a strong 9-5 pass
129	PTEBAC2SCI_94	% of entered pupils achieving the EBacc Science subject area with a 9-4 pass
130	PTEBAC2SCI_95	% of entered pupils achieving the EBacc Science subject area with a 9-5 pass
131	PTEBACHUM_94	% of entered pupils achieving the EBacc Humanities subject area with a 9-4 pass
132	PTEBACHUM_95	% of entered pupils achieving the EBacc Humanities subject area with a 9-5 pass
133	PTEBACLAN_94	% of entered pupils achieving the EBacc Language subject area with a 9-4 pass
134	PTEBACLAN_95	% of entered pupils achieving the EBacc Language subject area with a 9-5 pass
135	SCIVACOV_PTQ_EE	Coverage of the English Baccalaureate Science Value Added indicators of those who entered for science
136	HUMVACOV_PTQ_EE	Coverage of the English Baccalaureate Humanities Value Added indicators of those who entered for humanities
137	LANVACOV_PTQ_EE	Coverage of the English Baccalaureate Language Value

		Added indicators of those who entered for languages
138	SCIVAMEA_PTQ_EE	English Baccalaureate Science Value Added measure
139	SCIVALOW_PTQ_EE	English Baccalaureate Science Value Added lower 95% confidence limit
140	SCIVAUPP_PTQ_EE	English Baccalaureate Science Value Added upper 95% confidence limit
141	HUMVAMEA_PTQ_EE	EBacc Humanities VA measure
142	HUMVALOW_PTQ_EE	English Baccalaureate Humanities Value Added lower 95% confidence limit
143	HUMVAUPP_PTQ_EE	English Baccalaureate Humanities Value Added upper 95% confidence limit
144	LANVAMEA_PTQ_EE	English Baccalaureate Languages Value Added measure
145	LANVALOW_PTQ_EE	English Baccalaureate Languages Value Added lower 95% confidence limit
146	LANVAUPP_PTQ_EE	English Baccalaureate Languages Value Added upper 95% confidence limit
147	TEBACENG_94	Number of pupils achieving EBacc English subject area with a standard 9-4 pass
148	TEBACENG_95	Number of pupils achieving EBacc English subject area with a strong 9-5 pass
149	TEBACMAT_94	Number of pupils achieving EBacc Maths subject area with a standard 9-4 pass
150	TEBACMAT_95	Number of pupils achieving EBacc Maths subject area with a strong 9-5 pass
151	TEBAC2SCI_94	Number of pupils achieving EBacc Science subject area with a 9-4 pass

152	TEBAC2SCI_95	Number of pupils achieving EBacc Science subject area with a 9-5 pass
153	TEBACHUM_94	Number of pupils achieving EBacc Humanities subject area with a 9-4 pass
154	TEBACHUM_95	Number of pupils achieving EBacc Humanities subject area with a 9-5 pass
155	TEBACLAN_94	Number of pupils achieving EBacc Language subject area with a 9-4 pass
156	TEBACLAN_95	Number of pupils achieving EBacc Language subject area with a 9-5 pass
157	TEBACC91	Number of pupils achieving the English Baccalaureate at grades 9-1
158	PTEBACC91	% of pupils achieving the English Baccalaureate at grades 9-1
159	TEBACENG91	Number of pupils achieving EBacc English subject area at grade 9-1
160	PTEBACENG91	% of pupils achieving the EBacc English subject area at grade 9-1
161	TEBACMAT91	Number of pupils achieving EBacc Maths subject area at grade 9-1
162	PTEBACMAT91	% of pupils achieving the EBacc Maths subject area at grade 9-1
163	TEBAC2SCI91	Number of pupils achieving EBacc Science subject area with grades 9-1
164	PTEBAC2SCI91	% entered pupils achieving the EBacc Science subject area with grades 9-1
165	TEBACHUM91	Number of pupils achieving EBacc Humanities subject area with grades 9-1

166	PTEBACHUM91	% entered pupils achieving the EBacc Humanities subject area with grades 9-1
167	TEBACLAN91	Number of pupils achieving EBacc Language subject area with grades 9-1
168	PTEBACLAN91	% of entered pupils achieving the EBacc Language subject area with grades 9-1
169	ATT8SCR_FSM6CLA1A	Average Attainment 8 score per disadvantaged pupil
170	P8PUP_FSM6CLA1A	Number of disadvantaged pupils in Progress 8 measure
171	TP8ADJ_FSM6CLA1A	Number of disadvantaged pupils in progress measure with adjusted scores
172	P8MEA_FSM6CLA1A	Adjusted Progress 8 measure - disadvantaged pupils
173	P8CILOW_FSM6CLA1A	Adjusted Progress 8 lower 95% confidence interval - disadvantaged pupils
174	P8CIUPP_FSM6CLA1A	Adjusted Progress 8 upper 95% confidence interval - disadvantaged pupils
175	P8MEA_FSM6CLA1A_ORIG	Unadjusted Progress 8 measure - disadvantaged pupils
176	P8CILOW_FSM6CLA1A_ORIG	Unadjusted Progress 8 lower 95% confidence interval - disadvantaged pupils
177	P8CIUPP_FSM6CLA1A_ORIG	Unadjusted Progress 8 upper 95% confidence interval - disadvantaged pupils
178	ATT8SCR_NFSM6CLA1A	Average Attainment 8 score per non-disadvantaged pupil
179	P8PUP_NFSM6CLA1A	Number of non-disadvantaged pupils in Progress 8 measure
180	TP8ADJ_NFSM6CLA1A	Number of non-disadvantaged pupils in progress measure with adjusted scores

181	P8MEA_NFSM6CLA1A	Adjusted Progress 8 measure – non-disadvantaged pupils
182	P8CILOW_NFSM6CLA1A	Progress 8 lower 95% confidence interval – non-disadvantaged pupils
183	P8CIUPP_NFSM6CLA1A	Progress 8 upper 95% confidence interval – non-disadvantaged pupils
184	P8MEA_NFSM6CLA1A_ORIG	Unadjusted Progress 8 measure – non-disadvantaged pupils
185	P8CILOW_NFSM6CLA1A_ORIG	Unadjusted Progress 8 lower 95% confidence interval – non-disadvantaged pupils
186	P8CIUPP_NFSM6CLA1A_ORIG	Unadjusted Progress 8 upper 95% confidence interval – non-disadvantaged pupils
187	ATT8SCRENG_FSM6CLA1A	Average Attainment 8 score per disadvantaged pupil for English element
188	P8MEAENG_FSM6CLA1A	Progress 8 measure for English element – disadvantaged pupils
189	P8MEAENG_CILOW_FSM6CLA1A	Lower 95% confidence interval for Progress 8 English element for disadvantaged pupils
190	P8MEAENG_CIUPP_FSM6CLA1A	Upper 95% confidence interval for Progress 8 English element for disadvantaged pupils
191	ATT8SCRMAT_FSM6CLA1A	Average Attainment 8 score per disadvantaged pupil for mathematics element
192	P8MEAMAT_FSM6CLA1A	Progress 8 measure for maths element – disadvantaged pupils
193	P8MEAMAT_CILOW_FSM6CLA1A	Lower 95% confidence interval for Progress 8 maths element for disadvantaged pupils
194	P8MEAMAT_CIUPP_FSM6CLA1A	Upper 95% confidence interval for Progress 8 maths element for disadvantaged pupils

195	ATT8SCREBAC_FSM6CLA1A	Average Attainment 8 score per disadvantaged pupil for EBacc element
196	P8MEAEBAC_FSM6CLA1A	Progress 8 measure for EBacc element – disadvantaged pupils
197	P8MEAEBAC_CILOW_FSM6CLA1A	Lower 95% confidence interval for Progress 8 EBacc element for disadvantaged pupils
198	P8MEAEBAC_CIUPP_FSM6CLA1A	Upper 95% confidence interval for Progress 8 EBacc element for disadvantaged pupils
199	ATT8SCROPEN_FSM6CLA1A	Average Attainment 8 score per disadvantaged pupil for open element
200	P8MEAOPEN_FSM6CLA1A	Progress 8 measure for open element – disadvantaged pupils
201	P8MEAOPEN_CILOW_FSM6CLA1A	Lower 95% confidence interval for Progress 8 open element for disadvantaged pupils
202	P8MEAOPEN_CIUPP_FSM6CLA1A	Upper 95% confidence interval for Progress 8 open element for disadvantaged pupils
203	ATT8SCRENG_NFSM6CLA1A	Average Attainment 8 score per non-disadvantaged pupil for English element
204	P8MEAENG_NFSM6CLA1A	Progress 8 measure for English element – non-disadvantaged pupils
205	P8MEAENG_CILOW_NFSM6CLA1A	Lower 95% confidence interval for Progress 8 English element for non-disadvantaged pupils
206	P8MEAENG_CIUPP_NFSM6CLA1A	Upper 95% confidence interval for Progress 8 English element for non-disadvantaged pupils
207	ATT8SCRMAT_NFSM6CLA1A	Average Attainment 8 score per non-disadvantaged pupil for mathematics element
208	P8MEAMAT_NFSM6CLA1A	Progress 8 measure for maths element – non-disadvantaged pupils

209	P8MEAMAT_CILOW_NFSM6CLA1A	Lower 95% confidence interval for Progress 8 maths element for non-disadvantaged pupils
210	P8MEAMAT_CIUPP_NFSM6CLA1A	Upper 95% confidence interval for Progress 8 maths element for non-disadvantaged pupils
211	ATT8SCREBAC_NFSM6CLA1A	Average Attainment 8 score per non-disadvantaged pupil for EBacc element
212	P8MEAEBAC_NFSM6CLA1A	Progress 8 measure for EBacc element – non-disadvantaged pupils
213	P8MEAEBAC_CILOW_NFSM6CLA1A	Lower 95% confidence interval for Progress 8 EBacc element for non-disadvantaged pupils
214	P8MEAEBAC_CIUPP_NFSM6CLA1A	Upper 95% confidence interval for Progress 8 EBacc element for non-disadvantaged pupils
215	ATT8SCROPEN_NFSM6CLA1A	Average Attainment 8 score per non-disadvantaged pupil for open element
216	P8MEAOPEN_NFSM6CLA1A	Progress 8 measure for open element – non-disadvantaged pupils
217	P8MEAOPEN_CILOW_NFSM6CLA1A	Lower 95% confidence interval for Progress 8 open element for non-disadvantaged pupils
218	P8MEAOPEN_CIUPP_NFSM6CLA1A	Upper 95% confidence interval for Progress 8 open element for non-disadvantaged pupils
219	ATT8SCROPENG_FSM6CLA1A	Average Attainment 8 score per disadvantaged pupil for open element – GCSE only
220	ATT8SCROPENNG_FSM6CLA1A	Average Attainment 8 score per disadvantaged pupil for open element – non-GCSE only
221	ATT8SCROPENG_NFSM6CLA1A	Average Attainment 8 score per non-disadvantaged pupil for open element – GCSE only

222	ATT8SCROPENNG_NFSM6CLA1A	Average Attainment 8 score per non-disadvantaged pupil for open element – non-GCSE only
223	DIFFN_ATT8	Difference between Attainment 8 for disadvantaged pupils in school/LA and non-disadvantaged pupils nationally
224	DIFFN_P8MEA	Difference between Progress 8 measure for disadvantaged pupils in school/LA and non-disadvantaged pupils nationally
225	ATT8SCR_LO	Average Attainment 8 score per pupil with low prior attainment
226	P8PUP_LO	Number of pupils with low prior attainment included in Progress 8 measure
227	TP8ADJ_LO	Number of pupils with low prior attainments in progress measure with adjusted scores
228	P8MEA_LO	Adjusted Progress 8 measure – pupils with low prior attainments
229	P8CILOW_LO	Adjusted Progress 8 lower 95% confidence interval – pupils with low prior attainments
230	P8CIUPP_LO	Adjusted Progress 8 upper 95% confidence interval – pupils with low prior attainments
231	P8MEA_LO_ORIG	Unadjusted Progress 8 measure – pupils with low prior attainments
232	P8CILOW_LO_ORIG	Unadjusted Progress 8 lower 95% confidence interval – pupils with low prior attainments
233	P8CIUPP_LO_ORIG	Unadjusted Progress 8 upper 95% confidence interval – pupils with low prior attainments
234	ATT8SCR_AV	Average Attainment 8 score per pupil with middle prior attainment

235	P8PUP_AV	Number of pupils with middle prior attainment included in Progress 8 measure
236	TP8ADJ_AV	Number of pupils with middle prior attainments in progress measure with adjusted scores
237	P8MEA_AV	Adjusted Progress 8 measure – pupils with middle prior attainment
238	P8CILOW_AV	Progress 8 lower 95% confidence interval – pupils with middle prior attainment
239	P8CIUPP_AV	Progress 8 upper 95% confidence interval – pupils with middle prior attainment
240	P8MEA_AV_ORIG	Unadjusted Progress 8 measure – pupils with middle prior attainments
241	P8CILOW_AV_ORIG	Unadjusted Progress 8 lower 95% confidence interval – pupils with middle prior attainments
242	P8CIUPP_AV_ORIG	Unadjusted Progress 8 upper 95% confidence interval – pupils with middle prior attainments
243	ATT8SCR_HI	Average Attainment 8 score per pupil with high prior attainment
244	P8PUP_HI	Number of pupils with high prior attainment included in Progress 8 measure
245	TP8ADJ_HI	Number of pupils with high prior attainments in progress measure with adjusted scores
246	P8MEA_HI	Adjusted Progress 8 measure – pupils with high prior attainment
247	P8CILOW_HI	Progress 8 lower 95% confidence interval – pupils with high prior attainment
248	P8CIUPP_HI	Progress 8 upper 95% confidence interval – pupils with high prior attainment

249	P8MEA_HI_ORIG	Unadjusted Progress 8 measure – pupils with high prior attainments
250	P8CILOW_HI_ORIG	Unadjusted Progress 8 lower 95% confidence interval – pupils with high prior attainments
251	P8CIUPP_HI_ORIG	Unadjusted Progress 8 upper 95% confidence interval – pupils with high prior attainments
252	ATT8SCR_EAL	Average Attainment 8 score per pupil for whom English is an additional language
253	ATT8SCRENG_EAL	Average Attainment 8 score per pupil for whom English is an additional language for English element
254	ATT8SCRMAT_EAL	Average Attainment 8 score per pupil for whom English is an additional language for mathematics element
255	ATT8SCREBAC_EAL	Average Attainment 8 score per pupil for whom English is an additional language for EBacc element
256	ATT8SCROPEN_EAL	Average Attainment 8 score per pupil for whom English is an additional language for open element
257	ATT8SCROPENG_EAL	Average Attainment 8 score per pupil for whom English is an additional language – GCSE only
258	ATT8SCROPENNG_EAL	Average Attainment 8 score per pupil for whom English is an additional language – non-GCSE only
259	P8PUP_EAL	Number of pupils for whom English is an additional language included in Progress 8 measure
260	TP8ADJ_EAL	Number of pupils for whom English is an additional language

		in progress measure with adjusted scores
261	P8MEA_EAL	Adjusted Progress 8 measure – pupils for whom English is an additional language
262	P8CILOW_EAL	Adjusted Progress 8 lower 95% confidence interval – pupils for whom English is an additional language
263	P8CIUPP_EAL	Adjusted Progress 8 upper 95% confidence interval – pupils for whom English is an additional language
264	P8MEA_EAL_ORIG	Unadjusted Progress 8 measure – pupils for whom English is an additional language
265	P8CILOW_EAL_ORIG	Unadjusted Progress 8 lower 95% confidence interval – pupils for whom English is an additional language
266	P8CIUPP_EAL_ORIG	Unadjusted Progress 8 upper 95% confidence interval – pupils for whom English is an additional language
267	ATT8SCR_GIRLS	Average Attainment 8 score per girl
268	ATT8SCRENG_GIRLS	Average Attainment 8 score per girl for English element
269	ATT8SCRMAT_GIRLS	Average Attainment 8 score per girl for mathematics element
270	ATT8SCREBAC_GIRLS	Average Attainment 8 score per girl for EBacc element
271	ATT8SCROPEN_GIRLS	Average Attainment 8 score per girl for open element
272	ATT8SCROPENG_GIRLS	Average Attainment 8 score per girl – GCSE only
273	ATT8SCROPENNG_GIRLS	Average Attainment 8 score per girl – non-GCSE only
274	P8PUP_GIRLS	Number of girls included in Progress 8 measure

275	TP8ADJ_GIRLS	Number of girls in progress measure with adjusted scores
276	P8MEA_GIRLS	Adjusted Progress 8 measure – girls
277	P8CILOW_GIRLS	Adjusted Progress 8 lower 95% confidence interval – girls
278	P8CIUPP_GIRLS	Adjusted Progress 8 upper 95% confidence interval – girls
279	P8MEA_GIRLS_ORIG	Unadjusted Progress 8 measure – girls
280	P8CILOW_GIRLS_ORIG	Unadjusted Progress 8 lower 95% confidence interval – girls
281	P8CIUPP_GIRLS_ORIG	Unadjusted Progress 8 upper 95% confidence interval – girls
282	ATT8SCR_BOYS	Average Attainment 8 score per boy
283	ATT8SCRENG_BOYS	Average Attainment 8 score per boy for English element
284	ATT8SCRMAT_BOYS	Average Attainment 8 score per boy for mathematics element
285	ATT8SCREBAC_BOYS	Average Attainment 8 score per boy for EBacc element
286	ATT8SCROPEN_BOYS	Average Attainment 8 score per boy for open element
287	ATT8SCROPENG_BOYS	Average Attainment 8 score per boy – GCSE only
288	ATT8SCROPENNG_BOYS	Average Attainment 8 score per boy – non-GCSE only
289	P8PUP_BOYS	Number of boys included in Progress 8 measure
290	TP8ADJ_BOYS	Number of boys in progress measure with adjusted scores
291	P8MEA_BOYS	Adjusted Progress 8 measure – boys
292	P8CILOW_BOYS	Adjusted Progress 8 lower 95% confidence interval – boys
293	P8CIUPP_BOYS	Adjusted Progress 8 upper 95% confidence interval – boys
294	P8MEA_BOYS_ORIG	Unadjusted Progress 8 measure – boys

295	P8CILOW_BOYS_ORIG	Unadjusted Progress 8 lower 95% confidence interval - boys
296	P8CIUPP_BOYS_ORIG	Unadjusted Progress 8 upper 95% confidence interval - boys
297	ATT8SCR_NMOB	Average Attainment 8 score per non-mobile pupil
298	ATT8SCRENG_NMOB	Average Attainment 8 score per non-mobile pupil for English element
299	ATT8SCRMAT_NMOB	Average Attainment 8 score per non-mobile pupil for mathematics element
300	ATT8SCREBAC_NMOB	Average Attainment 8 score per non-mobile pupil for EBacc element
301	ATT8SCROPEN_NMOB	Average Attainment 8 score per non-mobile pupil for open element
302	ATT8SCROPENG_NMOB	Average Attainment 8 score per non-mobile pupil - GCSE only
303	ATT8SCROPENNG_NMOB	Average Attainment 8 score per non-mobile pupil - non-GCSE only
304	P8PUP_NMOB	Number of non-mobile pupils included in Progress 8 measure
305	TP8ADJ_NMOB	Number of non-mobile pupils in progress measure with adjusted scores
306	P8MEA_NMOB	Adjusted Progress 8 measure - non-mobile pupils
307	P8CILOW_NMOB	Adjusted Progress 8 lower 95% confidence interval - non-mobile pupils
308	P8CIUPP_NMOB	Adjusted Progress 8 upper 95% confidence interval - non-mobile pupils
309	P8MEA_NMOB_ORIG	Unadjusted Progress 8 measure - non-mobile pupils

310	P8CILOW_NMOB_ORIG	Unadjusted Progress 8 lower 95% confidence interval – non-mobile pupils
311	P8CIUPP_NMOB_ORIG	Unadjusted Progress 8 upper 95% confidence interval – non-mobile pupils
312	ATT8SCR_17	Average Attainment 8 score per pupil – 2017
313	P8PUP_17	Number of pupils in progress measure – 2017
314	P8MEA_17	Progress 8 measure – 2017
315	P8CILOW_17	Progress 8 lower 95% confidence interval – 2017
316	P8CIUPP_17	Progress 8 upper 95% confidence interval – 2017
317	ATT8SCR_FSM6CLA1A_17	Average Attainment 8 score per disadvantaged pupil – 2017
318	P8PUP_FSM6CLA1A_17	Number of disadvantaged pupils in progress measure – 2017
319	P8MEA_FSM6CLA1A_17	Progress 8 measure – disadvantaged pupils – 2017
320	P8CILOW_FSM6CLA1A_17	Progress 8 lower 95% confidence interval – disadvantaged pupils – 2017
321	P8CIUPP_FSM6CLA1A_17	Progress 8 upper 95% confidence interval – disadvantaged pupils – 2017
322	ATT8SCR_NFSM6CLA1A_17	Average Attainment 8 score per non-disadvantaged pupil – 2017
323	P8PUP_NFSM6CLA1A_17	Number of non-disadvantaged pupils in progress measure – 2017
324	P8MEA_NFSM6CLA1A_17	Progress 8 measure – non-disadvantaged pupils – 2017
325	P8CILOW_NFSM6CLA1A_17	Progress 8 lower 95% confidence interval – non-disadvantaged pupils – 2017
326	P8CIUPP_NFSM6CLA1A_17	Progress 8 upper 95% confidence interval – non-disadvantaged pupils – 2017

327	ATT8SCR_18	Average Attainment 8 score per pupil – 2018
328	P8PUP_18	Number of pupils in progress measure – 2018
329	P8MEA_18	Progress 8 measure – 2018
330	P8CILOW_18	Progress 8 lower 95% confidence interval – 2018
331	P8CIUPP_18	Progress 8 upper 95% confidence interval – 2018
332	ATT8SCR_FSM6CLA1A_18	Average Attainment 8 score per disadvantaged pupil – 2018
333	P8PUP_FSM6CLA1A_18	Number of disadvantaged pupils in progress measure – 2018
334	P8MEA_FSM6CLA1A_18	Progress 8 measure – disadvantaged pupils – 2018
335	P8CILOW_FSM6CLA1A_18	Progress 8 lower 95% confidence interval – disadvantaged pupils – 2018
336	P8CIUPP_FSM6CLA1A_18	Progress 8 upper 95% confidence interval – disadvantaged pupils – 2018
337	ATT8SCR_NFSM6CLA1A_18	Average Attainment 8 score per non-disadvantaged pupil – 2018
338	P8PUP_NFSM6CLA1A_18	Number of non-disadvantaged pupils in progress measure – 2018
339	P8MEA_NFSM6CLA1A_18	Progress 8 measure – non-disadvantaged pupils – 2018
340	P8CILOW_NFSM6CLA1A_18	Progress 8 lower 95% confidence interval – non-disadvantaged pupils – 2018
341	P8CIUPP_NFSM6CLA1A_18	Progress 8 upper 95% confidence interval – non-disadvantaged pupils – 2018
342	TEBACC_ELO_PTQ_EE	Number of pupils in low prior attainment band with entries in all EBacc subject areas
343	PTEBACC_ELO_PTQ_EE	EBacc entered % by low prior attainment

344	PTEBACCLO_94	EBacc achieved % by low prior attainment – with standard 9-4 passes in English and maths
345	PTEBACCLO_95	EBacc achieved % by low prior attainment – with 9-5 passes
346	TEBACC_EAV_PTQ_EE	Number of pupils in middle prior attainment band with entries in all EBacc subject areas
347	PTEBACC_EAV_PTQ_EE	EBacc entered % by middle prior attainment
348	PTEBACCAV_94	EBacc achieved % by middle prior attainment – with 9-4 passes
349	PTEBACCAV_95	EBacc achieved % by middle prior attainment – with 9-5 passes
350	TEBACC_EHI_PTQ_EE	Number of pupils in high prior attainment band with entries in all EBacc subject areas
351	PTEBACC_EHI_PTQ_EE	EBacc entered % by high prior attainment
352	PTEBACCHI_94	EBacc achieved % by high prior attainment – with 9-4 passes
353	PTEBACCHI_95	EBacc achieved % by high prior attainment – with 9-5 passes
354	PTEBACC_EFSM6CLA1A_PTQ_EE	% of disadvantaged pupils entering all English Baccalaureate subject areas
355	PTEBACC_ENFSM6CLA1A_PTQ_EE	% of non-disadvantaged pupils entering all English Baccalaureate subject areas
356	PTEBACC_94_FSM6CLA1A	% of disadvantaged pupils achieving the English Baccalaureate – with 9-4 passes
357	PTEBACC_95_FSM6CLA1A	% of disadvantaged pupils achieving the English Baccalaureate – with 9-5 passes
358	PTEBACC_94_NFSM6CLA1A	% of non-disadvantaged pupils achieving the English Baccalaureate – with 9-4 passes

359	PTEBACC_95_NFSM6CLA1A	% of non-disadvantaged pupils achieving the English Baccalaureate - with 9-5 passes
360	SCIVAMEA_LO_PTQ_EE	English Baccalaureate Science Value Added measure for pupils with low prior attainment
361	SCIVAMEA_AV_PTQ_EE	English Baccalaureate Science Value Added measure for pupils with middle prior attainment
362	SCIVAMEA_HI_PTQ_EE	English Baccalaureate Science Value Added measure for pupils with high prior attainment
363	SCIVAMEA_FSM6CLA1A_PTQ_EE	English Baccalaureate Science Value Added measure for disadvantaged pupils
364	SCIVAMEA_NFSM6CLA1A_PTQ_EE	English Baccalaureate Science Value Added measure for non-disadvantaged pupils
365	HUMVAMEA_LO_PTQ_EE	English Baccalaureate Humanities Value Added measure for pupils with low prior attainment
366	HUMVAMEA_AV_PTQ_EE	English Baccalaureate Humanities Value Added measure for pupils with middle prior attainment
367	HUMVAMEA_HI_PTQ_EE	English Baccalaureate Humanities Value Added measure for pupils with high prior attainment
368	HUMVAMEA_FSM6CLA1A_PTQ_EE	English Baccalaureate Humanities Value Added measure for disadvantaged pupils
369	HUMVAMEA_NFSM6CLA1A_PTQ_EE	English Baccalaureate Humanities Value Added measure for non-disadvantaged pupils
370	LANVAMEA_LO_PTQ_EE	English Baccalaureate Languages Value Added measure for pupils with low prior attainment
371	LANVAMEA_AV_PTQ_EE	English Baccalaureate Languages Value Added measure for pupils with middle prior attainment

372	LANVAMEA_HI_PTQ_EE	English Baccalaureate Languages Value Added measure for pupils with high prior attainment
373	LANVAMEA_FSM6CLA1A_PTQ_EE	English Baccalaureate Languages Value Added measure for disadvantaged pupils
374	LANVAMEA_NFSM6CLA1A_PTQ_EE	English Baccalaureate Languages Value Added measure for non-disadvantaged pupils
375	SCIVAUPP_FSM6CLA1A_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Science Value Added measure for disadvantaged pupils
376	SCIVALOW_FSM6CLA1A_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Science Value Added measure for disadvantaged pupils
377	SCIVAUPP_NFSM6CLA1A_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Science Value Added measure for non-disadvantaged pupils
378	SCIVALOW_NFSM6CLA1A_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Science Value Added measure for non-disadvantaged pupils
379	SCIVAUPP_LO_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Science Value Added measure for pupils with low prior attainment
380	SCIVALOW_LO_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Science Value Added measure for pupils with low prior attainment
381	SCIVAUPP_AV_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Science Value Added measure for pupils with middle prior attainment
382	SCIVALOW_AV_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Science

		Value Added measure for pupils with middle prior attainment
383	SCIVAUPP_HI_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Science Value Added measure for pupils with high prior attainment
384	SCIVALOW_HI_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Science Value Added measure for pupils with high prior attainment
385	HUMVAUPP_FSM6CLA1A_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Humanities Value Added measure for disadvantaged pupils
386	HUMVALOW_FSM6CLA1A_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Humanities Value Added measure for disadvantaged pupils
387	HUMVAUPP_NFSM6CLA1A_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Humanities Value Added measure for non-disadvantaged pupils
388	HUMVALOW_NFSM6CLA1A_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Humanities Value Added measure for non-disadvantaged pupils
389	HUMVAUPP_LO_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Humanities Value Added measure for pupils with low prior attainment
390	HUMVALOW_LO_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Humanities Value Added measure for pupils with low prior attainment
391	HUMVAUPP_AV_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Humanities Value Added measure for pupils with middle prior attainment
392	HUMVALOW_AV_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Humanities

		Value Added measure for pupils with middle prior attainment
393	HUMVAUPP_HI_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Humanities Value Added measure for pupils with high prior attainment
394	HUMVALOW_HI_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Humanities Value Added measure for pupils with high prior attainment
395	LANVAUPP_FSM6CLA1A_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Languages Value Added measure for disadvantaged pupils
396	LANVALOW_FSM6CLA1A_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Languages Value Added measure for disadvantaged pupils
397	LANVAUPP_NFSM6CLA1A_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Languages Value Added measure for non-disadvantaged pupils
398	LANVALOW_NFSM6CLA1A_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Languages Value Added measure for non-disadvantaged pupils
399	LANVAUPP_LO_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Languages Value Added measure for pupils with low prior attainment
400	LANVALOW_LO_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Languages Value Added measure for pupils with low prior attainment
401	LANVAUPP_AV_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Languages Value Added measure for pupils with middle prior attainment
402	LANVALOW_AV_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Languages

		Value Added measure for pupils with middle prior attainment
403	LANVAUPP_HI_PTQ_EE	Upper 95% confidence limit for English Baccalaureate Languages Value Added measure for pupils with high prior attainment
404	LANVALOW_HI_PTQ_EE	Lower 95% confidence limit for English Baccalaureate Languages Value Added measure for pupils with high prior attainment
405	PTEBACC_E_17_PTQ_EE	Percentage of pupils entering all English Baccalaureate subject areas in 2017
407	PTEBACC_94_17	% of KS4 pupils achieving the Ebacc – with standard 9-4 passes in English and maths in 2017
408	PTEBACC_95_17	% of KS4 pupils achieving the Ebacc – with strong 9-5 passes in English and maths in 2017
409	PTEBACC_E_18_PTQ_EE	% of pupils entering all English Baccalaureate subject areas in 2018
410	PTEBACC_94_18	% of KS4 pupils achieving the Ebacc – with standard 9-4 passes in English and maths in 2018
411	PTEBACC_95_18	% of KS4 pupils achieving the Ebacc – with strong 9-5 passes in English and maths in 2018
412	PBEBACC_E_PTQ_EE	Percentage of boys with entries in all English Baccalaureate subject areas
413	PBEBACC_94	% of KS4 boys achieving the Ebacc – with 9-4 passes
414	PBEBACC_95	% of KS4 boys achieving the Ebacc – with 9-5 passes
415	PGEBACC_E_PTQ_EE	Percentage of girls with entries in all English Baccalaureate subject areas

416	PGEBACC_94	% of KS4 girls achieving the Ebacc – with 9-4 passes
417	PGEBACC_95	% of KS4 girls achieving the Ebacc – with 9-5 passes
418	PTEBACC_ENMOB_PTQ_EE	Percentage of non-mobile pupils with entries in all English Baccalaureate subject areas
419	PTEBACCNMOB_94	Percentage of non-mobile pupils achieving the English Baccalaureate with 9-4 passes
420	PTEBACCNMOB_95	Percentage of non-mobile pupils achieving the English Baccalaureate with 9-5 passes
421	PTEBACC_EEAL_PTQ_EE	Percentage of pupils for whom English is an additional language with entries in all English Baccalaureate subject areas
422	PTEBACCEAL_94	Percentage of pupils for whom English as an additional language achieving the English Baccalaureate with 9-4 passes
423	PTEBACCEAL_95	Percentage of pupils for whom English as an additional language achieving the English Baccalaureate with 9-5 passes
424	PTEBACC_EFSM6CLA1A_17	Percentage of disadvantaged pupils entering all English Baccalaureate subject areas in 2017
425	PTEBACC_94_FSM6CLA1A_17	Percentage of disadvantaged pupils achieving the English Baccalaureate at grades 9-4 in 2017
426	PTEBACC_95_FSM6CLA1A_17	Percentage of disadvantaged pupils achieving the English Baccalaureate at grades 9-5 in 2017
427	PTEBACC_ENFSM6CLA1A_17	Percentage of non-disadvantaged pupils entering all

		English Baccalaureate subject areas in 2017
428	PTEBACC_94_NFSM6CLA1A_17	Percentage of non-disadvantaged pupils achieving the English Baccalaureate at grade 9-4 in 2017
429	PTEBACC_95_NFSM6CLA1A_17	Percentage of non-disadvantaged pupils achieving the English Baccalaureate at grade 9-5 in 2017
430	PTEBACC_EFSM6CLA1A_18	% of disadvantaged pupils entering all English Baccalaureate subject areas in 2018
431	PTEBACC_94_FSM6CLA1A_18	% of disadvantaged pupils achieving the English Baccalaureate including 9-4 passes in English and maths in 2018
432	PTEBACC_95_FSM6CLA1A_18	% of disadvantaged pupils achieving the English Baccalaureate including 9-5 passes in English and maths in 2018
433	PTEBACC_ENFSM6CLA1A_18	% of non-disadvantaged pupils entering all English Baccalaureate subject areas in 2018
434	PTEBACC_94_NFSM6CLA1A_18	% of non-disadvantaged pupils achieving the English Baccalaureate including 9-4 passes in English and maths in 2018
435	PTEBACC_95_NFSM6CLA1A_18	% of non-disadvantaged pupils achieving the English Baccalaureate including 9-5 passes in English and maths in 2018
436	PT5EM_94	% of pupils achieving Level 2 threshold including standard

		passes 9-4 in both English and Maths GCSEs
437	PT5EM_94_17	% of pupils achieving Level 2 threshold including standard passes 9-4 in both English and Maths GCSEs in 2017
438	PT5EM_94_18	% of pupils achieving Level 2 threshold including standard passes 9-4 in both English and Maths GCSEs
439	PTANYQ_PTQ_EE	Percentage of pupils achieving any qualifications
440	PTL2BASICS_94_17	% of pupils achieving 9-4 passes in GCSE English and maths in 2017
441	PTL2BASICS_95_17	% of pupils achieving 9-5 passes in GCSE English and maths in 2017
442	PTL2BASICS_94_18	% of pupils achieving 9-4 passes in GCSE English and maths in 2018
443	PTL2BASICS_95_18	% of pupils achieving 9-5 passes in GCSE English and maths in 2018
444	PTFSM6CLA1ABASICS_94	% of disadvantaged pupils achieving standard 9-4 passes in GCSE English and maths
445	PTNOTFSM6CLA1ABASICS_94	% of non-disadvantaged pupils achieving standard 9-4 passes in GCSE English and maths
446	TBASICSLO_94	Number of pupils in low prior attainment band who achieved standard 9-4 passes in English and maths
447	PTBASICSLO_94	% of pupils in low prior attainment band who achieved standard 9-4 passes in English and maths
448	TBASICSAV_94	Number of pupils in middle prior attainment band who achieved

		standard 9-4 passes in English and maths
449	PTBASICSAV_94	% pupils in middle prior attainment band who achieved standard 9-4 passes in English and maths
450	TBASICSHI_94	Number of pupils in high prior attainment band who achieved standard 9-4 passes in English and maths
451	PTBASICSHI_94	% pupils in high prior attainment band who achieved standard 9-4 passes in English and maths
452	PBL2BASICS_94	% of boys achieving standard 9-4 passes in both English and mathematics GCSEs
453	PGL2BASICS_94	% of girls achieving standard 9-4 passes in both English and mathematics GCSEs
454	PTL2BASICSEAL_94	% of pupils achieving standard 9-4 passes in both English and mathematics GCSEs and for whom English is an additional language
455	PTL2BASICSNMOB_94	% of non-mobile pupils achieving standard 9-4 passes in both English and mathematics GCSEs
456	PTFSM6CLA1ABASICS_95	% of disadvantaged pupils achieving strong 9-5 passes in GCSE English and maths
457	PTNOTFSM6CLA1ABASICS_95	% of non-disadvantaged pupils achieving strong 9-5 passes in GCSE English and maths
458	TBASICSLO_95	Number of pupils in low prior attainment band who achieved strong 9-5 passes in English and maths
459	PTBASICSLO_95	% of pupils in low prior attainment band who achieved

		strong 9-5 passes in English and maths
460	TBASICSAV_95	Number of pupils in middle prior attainment band who achieved strong 9-5 passes in English and maths
461	PTBASICSAV_95	% pupils in middle prior attainment band who achieved strong 9-5 passes in English and maths
462	TBASICSHI_95	Number of pupils in high prior attainment band who achieved strong 9-5 passes in English and maths
463	PTBASICSHI_95	% pupils in high prior attainment band who achieved strong 9-5 passes in English and maths
464	PBL2BASICS_95	% of boys achieving strong 9-5 passes in both English and mathematics GCSEs
465	PGL2BASICS_95	% of girls achieving strong 9-5 passes in both English and mathematics GCSEs
466	PTL2BASICSEAL_95	% of pupils achieving strong 9-5 passes in both English and mathematics GCSEs and for whom English is an additional language
467	PTL2BASICSNMOB_95	% of non-mobile pupils achieving strong 9-5 passes in both English and mathematics GCSEs
468	PTFSM6CLA1ABASICS_94_17	% of disadvantaged pupils achieving 9-4 in GCSE English and maths in 2017
469	PTFSM6CLA1ABASICS_95_17	% of disadvantaged pupils achieving 9-4 passes in GCSE English and maths in 2017
470	PTNOTFSMBASICS_94_17	% of non-disadvantaged pupils achieving 9-4 passes in GCSE English and maths in 2017

471	PTNOTFSM6CLA1ABASICS_95_17	% of non-disadvantaged pupils achieving 9-5 passes in GCSE English and maths in 2017
472	PTFSM6CLA1ABASICS_94_18	% of disadvantaged pupils achieving 9-4 passes in GCSE English and maths in 2018
473	PTFSM6CLA1ABASICS_95_18	% of disadvantaged pupils achieving 9-5 passes in GCSE English and maths in 2018
474	PTNOTFSM6CLA1ABASICS_94_18	% of non-disadvantaged pupils achieving 9-4 passes in GCSE English and maths in 2018
475	PTNOTFSM6CLA1ABASICS_95_18	% of non-disadvantaged pupils achieving 9-5 passes in GCSE English and maths in 2018
476	PTmultiLan_E	Percentage of pupils entering more than one language
477	PTtripleSci_E	Percentage of pupils entering biology, chemistry and physics
478	TFSM6CLA1A_17	Number of disadvantaged pupils at the end of key stage 4 in 2017
479	PTFSM6CLA1A_17	Percentage of pupils at the end of key stage 4 who were disadvantaged in 2017
480	TNOTFSM6CLA1A_17	Number of non-disadvantaged pupils at the end of key stage 4 in 2017
481	PTNOTFSM6CLA1A_17	Percentage of pupils at the end of key stage 4 who were not disadvantaged in 2017
482	TFSM6CLA1A_18	Number of disadvantaged pupils in 2018
483	PTFSM6CLA1A_18	% of pupils who were disadvantaged in 2018
484	TNOTFSM6CLA1A_18	Number of non-disadvantaged pupils in 2018
485	PTNOTFSM6CLA1A_18	% of pupils who were not disadvantaged in 2018
486	TAVENT_E_3NG_PTQ_EE	Average number of KS4 entries per pupil

487	TAVENT_E_3NG_LO_PTQ_EE	Average number of KS4 entries per pupil with low prior attainment
488	TAVENT_E_3NG_AV_PTQ_EE	Average number of KS4 entries per pupil with middle prior attainment
489	TAVENT_E_3NG_HI_PTQ_EE	Average number of KS4 entries per pupil with high prior attainment
490	TAVENT_E_3NG_FSM6CLA1A_PTQ_EE	Average number of KS4 entries per disadvantaged pupil
491	TAVENT_E_3NG_NFSM6CLA1A_PTQ_EE	Average number of KS4 entries per non-disadvantaged pupil
492	TAVENT_EFSM6CLA1A_17_PTQ_EE	Average number of KS4 entries per disadvantaged pupil in 2017
493	TAVENT_ENFSM6CLA1A_17_PTQ_EE	Average number of KS4 entries per non-disadvantaged pupil in 2017
494	TAVENT_EFSM6CLA1A_18_PTQ_EE	Average number of KS4 entries per disadvantaged pupil in 2018
495	TAVENT_ENFSM6CLA1A_18_PTQ_EE	Average number of KS4 entries per non-disadvantaged pupil in 2018
496	TAVENT_G_PTQ_EE	Average number of GCSE entries per pupil
497	TAVENT_GLO_PTQ_EE	Average number of GCSE entries per pupil with low prior attainment
498	TAVENT_GAV_PTQ_EE	Average number of GCSE entries per pupil with middle prior attainment
499	TAVENT_GHI_PTQ_EE	Average number of GCSE entries per pupil with high prior attainment
500	TAVENT_GFSM6CLA1A_PTQ_EE	Average number of GCSE entries per disadvantaged pupil
501	TAVENT_GNFSM6CLA1A_PTQ_EE	Average number of GCSE entries per non-disadvantaged pupil
502	TAVENT_GFSM6CLA1A_17_PTQ_EE	Average number of GCSE entries per disadvantaged pupil in 2017

503	TAVENT_GNFSM6CLA1A_17_PTQ_EE	Average number of GCSE entries per non-disadvantaged pupil in 2017
504	TAVENT_GFSM6CLA1A_18_PTQ_EE	Average number of GCSE entries per disadvantaged pupil in 2018
505	TAVENT_GNFSM6CLA1A_18_PTQ_EE	Average number of GCSE entries per non-disadvantaged pupil in 2018
506	P8_BANDING	Progress 8 banding shown on school performance tables website

Appendix C: United Learning Hegartymaths raw data according to skill example

HM ID	UPN	School name	Gender	Year gr	1_dura	1_atten	1_watc	1_score	2_dura	2_atten	2_watc	2_score	3_dura	3_atten	3_watc	3_score	4_dura	4_atten	4_watc	4_score
657097	L209219709016	[redacted]	m	8	40105	6	10960	100	30	2	0	100	17943	3	2336	100	12050	3	7813	100
656751	B209202306021	[redacted]	m	11	26436	4	0	100	27540	4	0	100	58	2	0	100	46	1	0	100
657149	J209690708018	[redacted]	m	8	26394	7	30239	100	56	4	10745	100	39	1	534	100	59	1	2054	100
657178	T305201409066	[redacted]	m	9	15718	7	16325	100	0	0	0	0	0	0	0	0	0	0	0	0
1170443	K209237410037	[redacted]	f	7	13468	65	59820	100	44	6	1990	100	0	0	0	0	0	0	0	0
238406	R931205607069	[redacted]	m	11	12714	5	3	100	8009	1	0	100	0	0	0	0	0	0	0	0
1255631	M355205206026	[redacted]	m	11	11567	1	0	100	638	2	0	100	0	0	0	0	0	0	0	0
1170430	Z209202311053	[redacted]	m	7	8050	11	520	100	4036	5	595	100	98	1	291	100	46	1	581	100
656689	W209249306069	[redacted]	f	11	7924	12	0	100	210	2	0	100	82	1	0	100	47	1	0	100
1255621	H355205206033	[redacted]	m	11	7687	4	0	100	22	2	0	100	66	3	0	100	34	2	0	100
534858	R837368109055	[redacted]	m	9	7507	11	522	100	48	3	0	100	100	2	0	100	0	0	0	0
657139	C316204310140	[redacted]	m	8	6747	1	4239	100	0	0	0	0	0	0	0	0	0	0	0	0
772165	L209286908023	[redacted]	m	9	6604	1	0	100	601	1	0	100	0	0	0	0	0	0	0	0
657167	H209216308008	[redacted]	m	9	6530	2	6260	100	35	1	0	100	128	1	0	90	4567	3	4672	100
484788	V356228412043	[redacted]	m	8	6492	38	0	100	67	2	0	100	0	0	0	0	170	16	14	100
657210	D209260608063	[redacted]	m	9	6488	1	2	100	4463	1	16	100	0	0	0	0	60	3	0	100
323604	D370203107013	[redacted]	f	11	6259	7	0	100	9513	1	0	100	1516	1	0	100	4110	1	0	100
226759	Y213208707052	[redacted]	f	10	6054	15	0	100	5820	11	0	100	9985	1	0	100	1956	11	0	100
251213	F302205707022	[redacted]	m	11	5950	20	7294	100	0	0	0	0	0	0	0	0	0	0	0	0
1255949	W355205210056	[redacted]	m	9	5814	2	0	100	0	0	0	0	0	0	0	0	0	0	0	0
1122306	T837368111028	[redacted]	f	7	5742	2	0	100	116	1	0	100	182	1	0	100	70	2	391	100
657287	F209281809007	[redacted]	m	9	5495	9	23649	100	38	6	17116	100	83	7	395	10	0	0	0	0
1097339	C373232913023	[redacted]	f	7	5034	11	133	100	3625	1	0	100	0	0	0	0	0	0	0	0
611081	F356350706004	[redacted]	m	11	4900	33	238	100	2906	17	0	100	3316	7	0	100	99	5	0	100
1255507	T355303407016	[redacted]	f	10	4828	31	0	100	101	10	0	100	0	0	0	0	1299	6	0	100
611066	N356100205046	[redacted]	m	11	4642	12	0	100	1339	4	0	100	4997	1	0	100	1261	10	0	100
657088	D209239009037	[redacted]	m	8	4476	1	2607	100	0	0	0	0	0	0	0	0	0	0	0	0
657107	W209234710063	[redacted]	f	8	4311	7	1118	100	84	1	0	100	187	1	0	100	182	1	0	100
438746	C213104609034	[redacted]	m	8	4257	1	0	100	0	0	0	0	0	0	0	0	0	0	0	0
657171	L209237409018	[redacted]	f	9	4176	12	3957	100	817	4	786	100	167	1	0	100	2520	4	4595	100
657259	H209342014002	[redacted]	m	9	4084	7	4518	100	24	1	0	100	0	0	0	0	0	0	0	0
958243	K320207805044	[redacted]	f	11	4043	1	0	100	0	0	0	0	0	0	0	0	73	1	0	100
1255846	D896272109009	[redacted]	f	8	3993	10	1	100	1986	9	0	100	142	5	0	100	593	4	0	100
610995	C356100305032	[redacted]	f	11	3953	1	0	100	0	0	0	0	0	0	0	0	3331	1	0	100
1251905	T208278317065	[redacted]	f	7	3900	1	613	100	74	1	455	100	2149	1	304	100	123	1	0	100
214292	U802345106037	[redacted]	m	11	3801	3	0	100	100	2	0	100	243	2	0	100	156	3	0	100
1256038	Q355209608040	[redacted]	m	9	3781	2	0	100	35	1	0	100	0	0	0	0	63	3	54	100
1255498	A355304007024	[redacted]	m	10	3764	1	0	100	0	0	0	0	0	0	0	0	0	0	0	0
1255641	N355205206017	[redacted]	f	11	3592	1	0	100	406	1	0	100	0	0	0	0	3070	1	0	100
101011	Q208278507030	[redacted]	m	10	3567	2	0	100	41	1	0	100	152	1	0	90	64	1	0	100
1255978	D355209608019	[redacted]	m	9	3494	1	0	100	0	0	0	0	0	0	0	0	0	0	0	0
269300	E301200108100	[redacted]	f	9	3485	1	0	100	0	0	0	0	0	0	0	0	0	0	0	0
1255812	G355205210026	[redacted]	f	7	3458	1	520	100	4169	1	0	100	0	0	0	0	3988	1	583	100

Appendix D: United Learning Hegartymaths schools' annual data example

HM ID	UPN	School name	Gende	Year g	1617 Logir	1617 Corr	1617 Incor	1617 Corr	1617 Asse	1617 Vide	1617 Fix U	1718 Logir	1718 Corr	1718 Incor	1718 Corr	1718 Asse	1718 Vide	1718 Fix U	1819 Logir	1819 Corr	1819 Incor	1819 Corr	1819 Asse	1819 Vide	1819 Fix U
463001	A888209709015	[redacted]	m	8	0	0	0	0	0	0	0	70	784	74	0	34066	2711	0	42	578	59	0	26507	14802	0
463002	C888209709055	[redacted]	m	8	1	71	4	0	949	0	0	50	370	82	0	18673	1146	0	47	405	119	0	28337	4984	0
463003	P888209709016	[redacted]	m	8	1	38	2	0	1057	0	0	40	413	36	0	22333	8618	0	75	429	40	0	29377	3371	0
463004	A888209708072	[redacted]	m	8	1	29	4	0	988	141	0	22	142	14	0	16756	5611	0	0	0	0	0	0	0	0
463005	M888209910039	[redacted]	f	8	1	68	10	0	1324	0	0	62	577	40	0	34727	19229	0	60	1062	86	0	67610	21676	0
463006	B888209709006	[redacted]	f	8	1	50	11	0	1318	55	0	81	504	74	1	50812	9089	0	70	462	456	6	49125	6135	3433
463007	V888334010019	[redacted]	m	8	7	372	5	3	5141	0	99	160	1374	49	28	99678	20939	2662	89	794	59	5	62312	9189	539
463008	N888210110007	[redacted]	f	8	1	6	16	0	751	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
463009	T888102409055	[redacted]	f	8	4	288	11	0	4980	0	0	83	802	225	3	57187	6523	353	66	823	213	0	71189	7117	0
463010	G931253308023	[redacted]	m	8	1	64	2	0	1470	13	0	38	334	89	0	31951	8225	0	46	366	88	2	50191	10611	0
463011	G888209709019	[redacted]	m	8	1	56	2	0	1325	0	0	52	462	53	0	31309	15760	0	47	480	49	0	42178	25918	0
463012	T888209709020	[redacted]	m	8	1	0	0	0	0	0	0	37	245	33	0	16048	9189	0	41	400	39	4	24252	3197	238
463013	L888374710014	[redacted]	m	8	0	0	0	0	0	0	0	34	299	84	0	18230	3643	0	31	326	26	0	31475	1469	0
463014	W888376411049	[redacted]	f	8	2	0	0	0	0	0	0	55	362	36	5	32721	4472	235	32	175	39	0	17788	3393	127
463015	M888334210019	[redacted]	f	8	1	72	5	0	1160	4	0	51	520	92	4	44069	22712	900	51	755	182	0	79689	31789	0
463016	Z888376409013	[redacted]	m	8	0	0	0	0	0	0	0	31	240	22	8	23588	11060	2021	37	418	26	2	43184	15905	0
463017	Q889300510010	[redacted]	m	8	1	32	5	0	1167	40	0	83	569	71	2	50145	2592	0	51	404	43	3	36312	598	552
463018	C888376408043	[redacted]	f	8	2	79	3	0	1143	0	0	50	407	60	1	38131	19668	0	58	545	75	2	60135	21764	63
463019	Y888330708026	[redacted]	f	8	1	47	5	0	1113	0	0	42	271	116	1	17656	1682	626	32	206	86	0	19862	3192	0
463020	L888103509037	[redacted]	f	8	0	0	0	0	0	0	0	55	499	150	0	40301	14630	0	63	370	249	0	57102	12674	0
463021	Z888102409059	[redacted]	m	8	0	0	0	0	0	0	0	40	351	20	3	44655	8552	0	41	316	48	0	52414	15973	0
463022	R888210509022	[redacted]	f	8	0	0	0	0	0	0	0	46	313	74	0	25374	5195	0	67	437	65	0	55924	10516	0
463023	Q888209910043	[redacted]	f	8	1	0	0	0	0	0	0	57	507	163	0	36811	6672	0	45	248	147	0	20770	5859	0
463024	Z888334210009	[redacted]	f	8	0	0	0	0	0	0	0	65	446	149	0	63584	4947	0	86	517	181	5	52740	10838	231
463025	G888209709021	[redacted]	m	8	1	68	4	0	1235	0	0	35	294	122	0	15538	10104	110	55	572	172	0	39372	6644	113
463026	R815100209002	[redacted]	f	8	0	0	0	0	0	0	0	54	467	92	23	38458	20469	4318	40	601	77	0	39622	27484	0
463027	W888209709049	[redacted]	m	8	1	62	2	0	958	0	0	46	354	116	0	24691	6878	0	63	616	260	0	38696	5446	0
463028	W888209709022	[redacted]	m	8	1	90	5	0	1475	9	0	67	546	42	13	22134	20554	848	59	593	53	0	30491	26319	0
463029	M888206710004	[redacted]	f	8	0	0	0	0	0	0	0	36	352	54	0	20953	11514	0	0	0	0	0	0	0	0
463030	V888210509024	[redacted]	m	8	1	48	0	0	938	0	0	43	496	36	0	37355	17710	0	61	537	59	0	64326	10532	0
463031	A88869056128B	[redacted]	f	8	3	67	2	0	2273	0	0	58	331	83	0	38695	12823	0	42	216	28	0	20214	4703	0
463032	K888334210008	[redacted]	m	8	1	67	2	0	962	2	0	71	598	19	11	33297	20955	2251	78	568	25	3	37085	16826	551
463033	Y888334710024	[redacted]	m	8	3	23	3	0	410	0	0	61	1218	240	23	45969	5387	2073	60	436	132	1	33647	4164	299
463034	L888209910048	[redacted]	f	8	0	0	0	0	0	0	0	84	451	9	5	53219	18858	221	71	727	12	0	67193	17545	0
463035	F888319510024	[redacted]	f	8	4	70	3	0	964	31	0	63	407	116	1	27922	12620	0	56	395	57	7	30941	4909	503
463037	L888313410003	[redacted]	f	8	1	62	6	0	1633	34	0	80	436	34	14	28606	24407	2486	56	794	29	0	44019	22621	0
463038	M888334710025	[redacted]	f	8	1	49	0	0	995	0	0	78	466	111	16	33684	24650	1647	72	567	130	4	41551	21690	300
463039	Z888376210026	[redacted]	m	8	0	0	0	0	0	0	0	57	334	49	0	45357	10793	0	51	409	83	0	29677	6008	0
463040	Y888333410012	[redacted]	f	8	1	76	6	0	968	0	0	54	392	211	4	28910	1536	183	54	289	165	0	18055	457	0
463041	N888334710016	[redacted]	f	8	2	21	9	0	684	0	0	56	330	163	0	14653	2004	0	86	525	105	0	29355	2739	0
463042	C888209710065	[redacted]	m	8	1	86	9	0	1296	42	0	79	428	156	0	33637	723	0	56	264	90	0	19290	4463	0
463043	Z888209608009	[redacted]	f	8	1	54	2	0	1780	0	0	43	336	101	0	34037	9520	0	56	287	101	0	26727	5319	0
463044	K888209709023	[redacted]	f	8	1	22	7	0	1219	18	0	69	407	101	0	37442	4611	0	109	498	66	1	36841	3575	0
463045	R888100009064	[redacted]	m	8	0	0	0	0	0	0	0	71	399	29	0	34495	15427	0	58	427	30	0	46123	14022	0
463046	G888209709050	[redacted]	f	8	1	23	6	0	1568	31	0	69	430	144	0	26826	3577	0	67	494	79	0	42568	7855	0

Appendix E: Screenshots of spreadsheet design for confidentiality

Here is a screen shot example of the Gov.uk data with empty column C, ready for the Hegartymaths team to input Y for the schools that use Hegartymaths:

1	4		5	6	15	25	28	29	30	31	32	33			34	35	36	37	38	39	40	41	42	43	44
RECTYP	URN	HM	SCHNAI	SCHNAI	NFTYPE	TOTPUI	TPUP	NUMGI	PBPUP	GPUP	PGPUP	KS2APS			TPRIORI	PTPRIO	TPRIORA	PTPRIOF	TPRIORI	PTPRIO	TFSM6C	PTFSM6	TNOTFS	PTNOTI	TEALGR
Record type (1=mainstream school; 2=special school; 4=local authority; 5=National (all schools); 7=National (maintained schools))	School Unique Reference Number	HM	School name	School now known as (used if the school has converted to an academy on or after 12 Sept 2018)		Number of pupils on roll (all ages)	Number of pupils at the end of key stage 4	Number of boys at the end of key stage 4	Percentage of pupils at the end of key stage 4 who are boys	Number of girls at the end of key stage 4	Percentage of pupils at the end key stage 4 who are girls	Key stage 2 Average Points Score of the cohort at the end of key stage 4	#	TRUE	Number of pupils at the end of key stage 4 with low prior attainment at the end of key stage 2	Percentage of pupils at the end of key stage 4 with low prior attainment at the end of key stage 2	Number of pupils at the end of key stage 4 with middle prior attainment at the end of key stage 2	Percentage of pupils at the end of key stage 4 with middle prior attainment at the end of key stage 2	Number of pupils at the end of key stage 4 with high prior attainment at the end of key stage 2	Percentage of pupils at the end of key stage 4 with high prior attainment at the end of key stage 2	Number of disadvantaged pupils at the end of key stage 4	Percentage of pupils at the end of key stage 4 who are disadvantaged	Number of non-disadvantaged pupils at the end of key stage 4	Percentage of pupils at the end of key stage 4 who are not disadvantaged	Number of pupils at the end of key stage 4 with English as additional language (EAL)
1	[redacted]		[redacted]		ACC	968	165	81	49%	84	51%	28.8	4752		19	12%	79	49%	64	40%	26	16%	139	84%	10
1	[redacted]		[redacted]		ACC	1594	240	121	50%	119	50%	29.5	7080		15	7%	99	43%	116	50%	63	26%	177	74%	54
1	[redacted]		[redacted]		CY	0	193	94	49%	99	51%	29.4	5674.2		14	8%	68	38%	98	54%	24	12%	169	88%	21
1	[redacted]		[redacted]		CY	964	148	76	51%	72	49%	28.5	4218		15	11%	75	54%	48	35%	23	16%	125	85%	6
1	[redacted]		[redacted]		AC	1308	227	121	53%	106	47%	28.2	6401.4		24	11%	108	51%	79	37%	54	24%	173	76%	40
1	[redacted]		[redacted]		AC	976	170	83	49%	87	51%	28.5	4845		17	11%	81	52%	59	38%	37	22%	133	78%	26
1	[redacted]		[redacted]		VC	756	110	60	55%	50	46%	28.5	3135		13	13%	47	46%	43	42%	33	30%	77	70%	21
1	[redacted]		[redacted]		ACC	822	161	82	51%	79	49%	29.9	4813.9		12	8%	59	37%	90	56%	35	22%	126	78%	15
1	[redacted]		[redacted]		CY	1812	242	121	50%	121	50%	27.1	6558.2		55	24%	105	45%	72	31%	117	48%	125	52%	225

And here is a screenshot of the anonymous results that were returned, which the Hegartymaths team copied and pasted as values only, using the pre-populated formulas I created.

1	4		5	6	15	25	28	29	30	31	32	33			34	35	36	37	38	39	40	41	42	43	44
RECTYPE	URN	HM	SCHNAME	SCHNAME_AC	NFTYPE	TOTPUPS	TPUP	NUMBOYS	PBPUP	GPUP	PGPUP	KS2APS			TPRIORLO	PTPRIORLO	TPRIORAV	PTPRIORAV	TPRIORHI	PTPRIORHI	TFSM6CLA1A	PTFSM6CLA1A	TNOTFSM6CLA	PTNOTFSM6CI	TEALGRP2
Record type (1=mainstream school; 2=special school; 4=local authority; 5=National (all schools); 7=National (maintained schools))	School Unique Reference Number	HM	School name	School now known as (used if the school has converted to an academy on or after 12 Sept 2018)		Number of pupils on roll (all ages)	Number of pupils at the end of key stage 4	Number of boys at the end of key stage 4	Percentage of pupils at the end of key stage 4 who are boys	Number of girls at the end of key stage 4	Percentage of pupils at the end key stage 4 who are girls	Key stage 2 Average Points Score of the cohort at the end of key stage 4	#	TRUE	Number of pupils at the end of key stage 4 with low prior attainment at the end of key stage 2	Percentage of pupils at the end of key stage 4 with low prior attainment at the end of key stage 2	Number of pupils at the end of key stage 4 with middle prior attainment at the end of key stage 2	Percentage of pupils at the end of key stage 4 with middle prior attainment at the end of key stage 2	Number of pupils at the end of key stage 4 with high prior attainment at the end of key stage 2	Percentage of pupils at the end of key stage 4 with high prior attainment at the end of key stage 2	Number of disadvantaged pupils at the end of key stage 4	Percentage of pupils at the end of key stage 4 who are disadvantaged	Number of non-disadvantaged pupils at the end of key stage 4	Percentage of pupils at the end of key stage 4 who are not disadvantaged	Number of pupils at the end of key stage 4 with English as additional language (EAL)
					STDEV.s	378.905646	61.8169245	39.670057	0.15993971	39.599884	0.15993938	1.234380969	1833.66355		9.72037328	0.0614252	29.6071829	0.09636577	37.5625093	0.13589322	27.267273	0.15503526	58.1751788	0.15502989	37.344763
					STDEV.p	378.718394	61.786375	39.6504523	0.15986067	39.580314	0.15986034	1.233770946	1832.75736		9.71556954	0.06139485	29.5925513	0.09631815	37.5439462	0.13582606	27.2537977	0.15495864	58.146429	0.15495327	37.3263075
		1012	HM schools			1056814	171548	86432	50.38%	85116	49.62%	28.56581028	4921373.7	28.68802726	17665	10.30%	76370	44.52%	69539	40.54%	48206	28.10%	123342	71.90%	29073
		2098	Non HM schools			2124941	350905	176439	50.28%	174466	49.72%	28.85605338	10157039.3	28.94526809	33759	9.62%	147916	42.15%	151809	43.26%	86704	24.71%	264201	75.29%	56225
					STDEV.p	400.898142	61.495404	43.20443	0.19175956	42.7749195	0.19175878	1.551331437	1817.84396		10.1038368	0.06487402	32.6845751	0.13203646	38.880293	0.17657966	26.3301045	0.14931809	56.5015109	0.14931708	37.949596
					STDEV.s	400.993719	61.5100649	43.2147303	0.19180528	42.7851174	0.1918045	1.551701286	1818.27735		10.1062456	0.06488948	32.6923673	0.13206794	38.8895624	0.17662175	26.3363818	0.14935369	56.5149813	0.14935268	37.9586435
		3110	Totals in reduced data			3181755	522453	262871	50%	259582	50%	28.8	15078413		51424	10%	224286	43%	221348	42%	134910	26%	387543	74%	85298
7			Totals All schools			3366207	542621	276670	51%	265951	49%	28.6			60688	12%	228580	45%	223661	44%	143816	27%	398805	74%	90069

Appendix F: Proportionate ethical review form

For Research Office Use ONLY:
Checklist No:
Date Received:

PROPORTIONATE ETHICAL REVIEW FORM

ETHICS REVIEW CHECKLIST

Your application must comprise the following four documents (please tick the boxes below to indicate that each section is complete):

Ethics Review Checklist	✓
Consent Material(s)	✓
Participant Information Material(s)	✓
Risk Assessment Form *(NB. This MUST be signed by your Head of Department/School)*	✓

Please attach copies of any documents to be used in the study:
(NB: These must be attached where they form part of your methodology)

Relevant permission letter(s)/email(s)	☐
Questionnaire	✓
Introductory letter(s)	☐
Data Collection Instruments	☐
Interview Questions	☐
Focus Group Guidelines	☐

Other (please give details):

ETHICS REVIEW CHECKLIST – PROPORTIONATE ETHICAL REVIEW

Sections A and B of this form **must** be completed for **every** research or knowledge exchange project that involves human or animal[1] participants, or the processing of data not in the public domain. These sections serve as a toolkit that will identify whether a full application for ethics approval needs to be submitted.

If the toolkit shows that there is **no need for a full ethical review**, Sections D, E, F and G should be completed in full and the checklist emailed to red.resgov@canterbury.ac.uk as described in Section C.

If the toolkit shows that **a full application is required**, this checklist should be set aside and an *Application for Faculty Research Ethics Panel Approval Form* – or an appropriate external application form – should be completed and submitted. **There is no need to complete both documents.**

IMPORTANT

Before completing this form, please refer to *Ethics Policy for Research Involving Human Participants* and the *Code of Practice for the Use of Sentient Animals in Research and Teaching* on the University Research website.

Please note that it is your responsibility in the conduct of your study to follow the policies and procedures set out in the University's Research Ethics website, and any relevant academic or professional guidelines. This includes providing appropriate information sheets and consent Materials, and ensuring confidentiality in the storage and use of data. Any significant change in the question, design or conduct over the course of the study should be notified to the **Faculty and/or other Research Ethics Panel** that received your original proposal. Depending on the nature of the changes, a new application for ethics approval may be required.

The principal researcher/project leader (or, where the principal researcher/project leader is a student, their supervisor) is responsible for exercising appropriate professional judgement in this review.

N.B. This checklist must be completed, reviewed, any actions taken and approved before potential participants are approached to take part in any research project.

Type of Project – please tick as appropriate			
Research	✓	Knowledge Exchange	☐

Section A: Applicant Details

A1. Name of applicant:	Athanasios Gidaropoulos		
A2. Status (please tick):	Postgraduate Student ✓	Staff Member ☐	
A3. Faculty/Department &	Education/Canterbury Christ Church College		

A4. Email address:	mortiyios@gmail.com
A5. Contact address:	80 Bromefield Stanmore Middlesex HA7 1AQ
A6. Telephone number	+44 7727665498

[1]Sentient animals, generally all vertebrates and certain invertebrates such as cephalopods and crustaceans

Section B: Ethics Checklist

Please answer each question by choosing 'YES' or 'NO' in the appropriate box. Consider each response carefully:

		Yes	No
1	Does the study involve participants who are particularly vulnerable or unable to give informed consent, or in unequal relationships? (N.B. The list of vulnerable groups is extensive, please consider the answer to this question carefully. If your own staff or students are participants within your research the answer to this question is 'Yes')	☐	✓
2	Will the study require the co-operation of a gatekeeper for initial access to any vulnerable groups or individuals to be recruited?	☐	✓
3	Will it be necessary for participants to take part in the study without usual informed consent procedures having been implemented in advance? (including but not restricted to; covert observation, certain ethnographic studies, involve the capturing of data from social media sources)	☐	✓
4	Will the study use deliberate deception? (N.B. This does not include randomly assigning participants to groups in an experimental design)	☐	✓
5	Will the study involve discussion of, or collection of information on, topics of a sensitive nature personal to the participants? (including but not restricted to sexual activity, drug use)	☐	✓
6	Are drugs, placebos or other substances (including but not restricted to food substances, vitamins) to be administered to human or animal participants?	☐	✓
7	Does the study involve invasive or intrusive procedures such as blood taking or muscle biopsy from human or animal participants?	☐	✓
8	Is physiological stress, pain, or more than mild physical discomfort to humans or animals, beyond the risks encountered in normal, life likely to result from the study?	☐	✓
9	Could the study induce psychological stress or anxiety or cause harm or negative consequences in humans (including the researcher) or animals beyond the risks encountered in normal life?	☐	✓
10	Will the study involve interaction with animals? (N.B. If you are simply observing them – e.g. in a zoo or in their natural habitat – without having any contact at all, you can answer "No")	☐	✓
11	Will the study involve prolonged or repetitive testing?	☐	✓
12	Will financial inducements (other than reasonable expenses and compensation for time) be offered to participants?	☐	✓
13	Is the study a survey or activity that involves University-wide recruitment or a representative sample of students from Canterbury Christ Church University? (N.B. The Student Survey Unit and the Student Communications Unit should	☐	✓

	be notified of plans for any extensive student surveys (i.e. research with 100 CCCU students or more))		
14	Will the study involve participants who may lack capacity to consent or are at risk of losing capacity to consent as defined by the Mental	☐	✓
15	Will the study involve recruitment of participants (excluding staff) through the NHS?	☐	✓
16	Will the study involve participants (Children or Adults) who are currently users of social services including those in care settings who are funded by social services or staff of social services departments?	☐	✓

NEXT: Please assess outcomes and actions by referring to Section C ➲

Section C: How to Proceed

<table>
<tr><th>Responses to Section B</th><th>Next steps</th></tr>
<tr><td>C1. ‘NO’ to all questions in Section B</td><td>Complete Sections D-F of this form, including attachments as appropriate, and email it to red.resgov@canterbury.ac.uk.
Once your application is assessed, and any follow up action taken, if it is given approval you will receive a letter confirming compliance with University Research Governance procedures. No research can be undertaken until this letter is issued.
Master’s students should retain copies of the form and letter; the letter should be bound into their research report or dissertation. Work that is submitted without this document will be returned un-assessed.</td></tr>
<tr><td colspan="2">C2. If you have answered ‘YES’ to any of the questions in Section B, you will need to describe more fully how you plan to deal with the ethical issues raised by your project. This does not mean that you cannot do the study, only that your proposal will need to be approved by a Research Ethics Panel. Depending upon which questions you answered ‘YES’ to, you should proceed as below:</td></tr>
<tr><td>a) ‘YES’ to any of questions 1 - 12 ONLY (i.e. not questions 13,14 or 15)</td><td>DO NOT complete this form.
Submit an application to your Faculty Ethics Panel (FEP) using your Faculty’s version of the Application for Faculty Research Ethics Panel Approval Form. This should be submitted to your faculty as directed on the form.</td></tr>
<tr><td>b) ‘YES’ to question 13</td><td>You have two options:
(i) If you answered ‘YES’ to question 13 ONLY you must send copies of this form (including attachments) to the Student Survey Unit and the Student Communications Unit. Subject to their agreement you may then proceed as at C1 above. (ii) If you answered ‘YES’ to question 13 PLUS any other of questions 1 - 12, you must proceed as at C2(b)(i) above and then submit an application to your Faculty Ethics Panel (FEP) as at C2(a).</td></tr>
<tr><td>c) ‘YES’ to questions 14 and 15</td><td>You DO NOT need to submit an application to your Faculty Ethics Panel (FEP).
INSTEAD, Please use the HRA decision making tool and proceed according to the instructions given.
Applications must be signed by the relevant faculty Director of Research or other nominated signatory prior to submission.
A satisfactory peer review must be completed.</td></tr>
</table>

	• Once approval is given, you must send a copy to the relevant FEP.
d) **'Yes' to question 16**	• If your study involves users of social services or social services staff you may need to undertake different processes: • If your study involves carers of people receiving NHS care or treatment please follow the HRA decision making tool and process outlined in c) above • If your study involves local social services staff or service users who are children or adults you should complete an application for full internal approval and also contact the relevant Research and Governance manager of the local authority or authorities involved for management approval to attach to your application. • If your study involves more than three local authority children's social services sites you will need to apply to the Association of Directors of Children's Social Services for approval • If your study involves four or more adult social services sites you will need to apply to the Association of Directors of Adult Social Service for approval.

Section D: Project Details

D1. Project title:	Hegartymaths: To what extent can it impact the outcomes for pupils learning mathematics in secondary schools within the UK?
D2. Start date of fieldwork	01/05/2019
D3. End date of fieldwork	31/03/2021
D4. Project summary *(This should be written in plain English avoiding overly academic language and acronyms)*	*Hegartymaths is online platform that has been adopted by a significant amount of schools in supporting teachers and students learn mathematics. It is primarily a bank of video tutorials that helps pupils learn mathematics topic by topic. The learning is assessed by quizzes that are taken by the students and tracked by the teachers.* *The purpose of this project is to find out if the anecdotal claims that Hegartymaths is a world-class tool in supporting pupils have much weight. I would like to conduct a large scale statistical study to look for correlations that answer the following:* - *To what extent does the use of Hegartymaths have an impact on student outcomes at GCSE?* - *Is there an association between GCSE outcomes and the self reported efficacy of Hegartymaths by pupils?* - *Is Hegartymaths more useful for the outcomes of pupils on certain topics/types of mathematical questions?* *A survey will question teachers on how they use Hegartymaths within the classroom. The ultimate goal here is to look for correlations that might shed some light in how teachers can best use Hegartymaths, as this varies quite a lot between schools and teachers. The teachers asked will be working at United Learning (multi-academy trust) Schools who all use Hegartymaths and have given me permission to access the data.*

Section E: Data protection

The *General Data Protection Regulation (GDPR)* applies to the processing of personal data across the EU. It builds on the Data Protection Act (DPA) 1998, which has been replaced by the DPA 2018. The GDPR introduces stringent requirements for protecting data and much greater accountability. It gives individuals more control over their personal data.

E1. Personal data	Will Personal Identifiable Information (also defined as personal data) be collected and/or processed? *YES/NO* *If you are in doubt, please refer to the guidance - General Data Protection Regulation (GDPR))*
• If you answered 'YES' to the question above please complete the rest of this section providing as much detail as possible using the guidance questions. *This should be written in plain English avoiding overly academic language and acronyms. It must contain as much information as possible on how your research will comply with the GDPR.* • If you answered 'NO' to the question above and having read the guidance are sure that no personal data will be collected or processed please move on to section F.	
E2. Data collection	• *What personal data will be collected? And what is the reason for this?* • *What is the lawful basis for the collection and processing of personal data? N.B This is likely to be consent but not in all cases! Please use the lawful basis tool produced by the ICO to determine, if you are in doubt: https://ico.org.uk/for-organisations/resources-and-support/getting-ready-for-the-gdpr-resources/lawful-basis-interactive-guidance-tool/*
E3. Subject access requests	• *What arrangements in place related to any actions required to respond to individual requests for access to their personal data (Subject Access Requests)? i.e. How are you ensuring that personal data can be quickly and easily extracted from the system and/or redacted?* • *If consent is your lawful basis, will participants be able to withdraw consent at any stage of the research? What is the process for this? What is the cut-off date for withdrawal?*

E4. Data access & sharing	• *Who will have access to the personal data? Any third party involvement? For students this will include your supervisor and examiner as a minimum.* • *Please list and define the roles of any third party organisations (including software providers or partner organisations) with an involvement in the processing of the personal data.* • *Have you ensured that all third party involvement in the processing of data is covered by a Data Sharing Agreement (with a data controller) or a Data Processing Agreement (with a data Processor)? (Please refer to CCCU guidance for further information.)https://cccu.canterbury.ac.uk/governance-and-legal-services/the-general-data-protection-regulation/data-sharing.aspx* • *Is this an international project? Will personal data be shared outside of the EEA? What safeguards are in place?*
E5. Participant recruitment, privacy & confidentiality	• *Are you using social media to recruit participants? How have you ensured the security surrounding your use of personal data in social media activities? How are you gaining consent? How are you informing participants of how their personal data will be used?* • *Are you undertaking any activities that could create privacy concerns for individuals due to personal intrusion? How will this be mitigated and addressed?* • *How will you ensure confidentiality? Please identify and list all the risks which could lead to a data breach.*
E6. Data quality	• *What processes do you have in place to check the dataset received or processed is, and will continue to be, relevant, adequate and not excessive?*
E7. Data storage	• *Where and how will personal data be stored? Have you consulted with the IT department in order to verify if they can offer a valid solution?* • *If stored external to CCCU systems, how are you ensuring that personal data is safely stored, processed and disposed of securely when no longer needed?* • *How long will personal data be kept/stored for? In what format will this be?*

Section F1: For Students Only

F1. Module name and number:	**1.**
F2. Course:	Doctorate in Education Generic Cohort 2 (2013) EDDPD2012DOCEDUC2013
F3. Name of Supervisor(s) or module Leader:	Lynn Revell
F4. Email address of Supervisor(s) or Module leader:	lynn.revell@canterbury.ac.uk

Section F2: For Supervisors

Please ensure that this form has been completed correctly and in full. It will delay the ethical approval process if the form is incorrect, incomplete or has not been proofread.

Please tick the appropriate boxes below. This application should not be submitted until all boxes are ticked:

The student has read the relevant documentation relating to the University's Research Governance, available on the University web pages at: https://cccu.canterbury.ac.uk/research-and-enterprise-development-centre/research-governance-and-ethics/research-governance-and-ethics.aspx	☐
Both myself and the student have read the relevant documentation relating to Data Protection and the GDPR, available on the University web pages at https://cccu.canterbury.ac.uk/governance-and-legal-services/governance-and-legal-services.aspx and I can confirm that this project fully complies.	☐
The chosen topic merits further investigation	☐
The student has the skills to carry out the project	☐
I can confirm that the participant information sheet is completed in full and is appropriate	☐
I have reviewed the procedures for participant recruitment and obtaining informed consent and can confirm that they are appropriate	☐
If a Disclosure & Barring Service (DBS) check is required, this has been carried out	☐

Comments from supervisor:

Section G: Declaration

- I certify that the information in this form is accurate to the best of my knowledge and belief and I take full responsibility for it.
- I certify that a risk assessment for this study has been carried out in compliance with the University's Health and Safety policy and has been approved and signed by the relevant Head of School/Department.
- I certify that my project proposal and methodology has been subject to '*peer review*' commensurate with the level of that research. For students this will be carried out by the supervisor and for staff by an appropriately qualified person independent of the research proposed.
- I certify that any required Disclosure & Barring Service (DBS) check has been carried out.
- I undertake to carry out this project under the terms specified in the Canterbury Christ Church University Research Governance Handbook.
- I undertake to inform the relevant Faculty Ethics Panel and Red.resgov@canterbury.ac.uk of any significant change in the question, design or conduct of the research over the course of the project. I understand that such changes may require a new application for ethics approval.
- I undertake to inform the **Contracts & Compliance Manager** at Red.resgov@canterbury.ac.uk in the **Research and Enterprise Integrity and Development Office** when the proposed study has been completed.
- I have read and understood the relevant University documentation relating to Data Protection and the GDPR and I am aware of my legal responsibility to comply with the terms of the GDPR and appropriate University policies and guidelines relating to the security and confidentiality of participant or other personal data.
- I understand that project records/data may be subject to inspection for audit purposes if required in future and that project records should be kept securely for five years or other specified period.
- I understand that the personal data about me contained in this application will be held by the **Research and Enterprise Integrity and Development Office** and **the relevant Faculty** and that this will be managed according to the principles established in the GDPR and appropriate University policies.

As the Principal Investigator for this study, I confirm that this application has been shared with all other members of the study team	(please tick) ✓

Principal Investigator	Supervisor or module leader (as appropriate)
Name: Athanasios Gidaropoulos Date: 24/04/2019	Name: Date:

Section H: Submission

This completed form along with all relevant documents should be sent as an attachment to a covering email, to Red.resgov@canterbury.ac.uk.

Please allow at least 4 weeks from the point that a completed submission is sent to the relevant Ethics Chair to receive an outcome.

N.B. YOU MUST include copies of the Participant Information materials and Consent Materials that you will be using in your study. Model versions on which to base these are appended below for your convenience – please note that if you choose to create your own forms then you must ensure that all relevant confidentiality and data protection information is included. If any required information is omitted your application will be returned to you for further action.

Copies of any data gathering tools such as questionnaires or focus group guidelines, and a COMPLETED & SIGNED HEALTH & SAFETY RISK ASSESSMENT FORM must be submitted. Guidance on completing your H&S Risk Assessment can be found here.

Canterbury Christ Church University

CONSENT FORM

Title of Project:	Hegartymaths: To what extent can it impact the outcomes for pupils learning mathematics in secondary schools within the UK?
Name of Researcher:	*Athanasios Gidaropoulos*

Contact details:

Address: *80 Bromefield*
Stanmore
Middlesex
HA7 1AQ

Tel: *+44 7727665498*

Email: *mortiyios@gmail.com*

Please initial box

1. I confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason.
3. I understand that any personal information that I provide to the researchers will be kept strictly confidential
4. I agree to take part in the above study.

__

Name of Participant:	Date:	Signature:

Name of person taking consent *(if different from researcher)*	Date:	Signature:
Researcher: Athanasios Gidaropoulos	Date:	Signature:

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<Insert - *TITLE OF RESEARCH PROJECT*>

PARTICIPANT INFORMATION SHEET

A research study is being conducted at Canterbury Christ Church University (CCCU) by *<your name and (if relevant) the names of any co-researchers>*

Background

<Set out the background to your study and the main aims, taking care to use plain English and avoid using overly academic language, technical terms and acronyms. Is this a funded research project? Please state here who the funder is and any third parties you will be working with on the project. Remember that the language you use here must be clearly understood to allow informed consent to be given>

What will you be required to do?

Participants in this study will be required to *<list what will be required of them – sufficient detail to allow informed consent is required>*

To participate in this research you must:

<Give a bullet point list of the eligibility criteria for participation in the study>

Procedures

You will be asked to *<give details of what you want your participants to do e.g. complete an online questionnaire, take part in a focus group. What, when, how, where etc>*

Feedback

<Give details of any feedback that you will provide to participants>

Confidentiality and Data Protection

On the legal basis of *<state the legal basis – this is likely to be consent but not always>* all data and personal information will be stored securely within CCCU premises in accordance with the General Data Protection Regulation (GDPR) and the University's own data protection policies. No unrelated or unnecessary personal data will be collected or stored. The following categories of personal data will be processed *<state the personal data categories that will be collected and processed>*. Personal data will be used *<state how personal data is to be used>*. Data can only be accessed by *<state whom; this will normally be at least the same person(s) listed in the initial paragraph of this sheet and any co-researchers. For students it will also include your supervisor and examiner as a minimum. Please also state here if data will be transferred outside of the European Economic Area (EEA)–if this is the case provide details of the recipients and the reason for this>*.

After completion of the study, all data will be made anonymous (i.e. all personal information associated with the data will be removed) and held for a period of *<state how long the data will be held for after the completion of the project. CCCU recommends 5 years>.*

Dissemination of results

<Explain, if known, how the results of the study will be published or otherwise disseminated. Any PhD or MA thesis will be published in the CCCU library and that should be referenced here>

Deciding whether to participate

If you have any questions or concerns about the nature, procedures or requirements for participation do not hesitate to contact me. Should you decide to participate, you will be free to (i) withdraw consent at any time without having to give a reason, (ii) request to see all your personal data held in association with this project, (iii) request that the processing of your personal data is restricted, (iv) request that your personal data is erased and no longer used for processing.

Process for withdrawing consent

You are free to withdraw consent at any time without having to give a reason. To do this *<state the process for withdrawal here. This may be as simple as the participant sending an email, or it may be more complex in the case of online surveys, audio and visual recordings etc>*

Any questions?

Please contact *<name of lead researcher>* on *<CCCU phone and CCCU email contact details; avoid giving personal contact details. Give the name of your University Department and its mailing address. For students please also include your supervisors contact details here>*

Draft Survey Questions

1. *What UL school do you work at?*
2. *What are the names of the classes you teach (as seen on Hegartymaths)?*
3. *What is the degree you hold?*
4. *How many years have you been teaching mathematics for?*
5. *On a scale of 1-5 (1 being least confident and 5 being most confident), how confident are you in your subject knowledge?*

6. *On a scale of 1-5 (1 being worst and 5 being best) how would you rate Hegartymaths overall?*
7. *On a scale of 1-5 (1 being worst and 5 being best) how would you rate Hegartymaths as a tool for revision?*
8. *On a scale of 1-5 (1 being worst and 5 being best) how would you rate the Hegartymaths videos as tutorials?*
9. *On a scale of 1-5 (1 being worst and 5 being best) how would you rate the Hegartymaths quizzes?*

10. *Do you set tasks on Hegartymaths for homework on a weekly basis?*
11. *How many tasks to you expect students to complete every week?*
12. *How much time do you expect students to spend on Hegartymaths per week?*
13. *Do you always expect pupils to watch the video tutorial before attempting the quiz?*
14. *Do students generally make notes when watching the videos?*
15. *Do you usually set the whole class the same task?*

16. *Do you use Hegartymaths to consolidate the learning you most recently taught?*
17. *Do you use Hegartymaths to revise topics you haven't taught for a while?*
18. *Do you use Hegartymaths to flip the learning?*
19. *Do you use Hegartymaths to target pupil weaknesses?*

Appendix G: Confirmation of ethics compliance

Canterbury Christ Church University

19th August 2019 Ref: 18/EDU/20C

Athanasios Gidaropoulos
c/o Faculty of Education

Dear Athanasios,

Confirmation of ethics compliance for your study – ***'Hegartymaths: To what extent can it impact the outcomes for pupils learning mathematics in secondary schools within the UK?'***

The Faculty Ethics Chair has reviewed your Ethics Review Checklist application and appropriate supporting documentation for the above project. The Chair has confirmed that your application complies fully with the requirements for proportionate ethical review, as set out in this University's Research Ethics and Governance Procedures.

In confirming compliance for your study, you are reminded that it is your responsibility to follow, as appropriate, the policies and procedures set out in the *Research Governance Framework* (http://www.canterbury.ac.uk/research-and-consultancy/governance-and-ethics/governance-and-ethics.aspx) and any relevant academic or professional guidelines. This includes providing, if appropriate, information sheets and consent forms, and ensuring confidentiality in the storage and use of data.

Any significant change in the question, design or conduct of the study over its course should be notified via email to red.resgov@canterbury.ac.uk and may require a new application for ethics approval.

It is a condition of compliance that you **must** inform red.resgov@canterbury.ac.uk once your research has completed.

Wishing you every success with your research.

Yours sincerely,

Penny

Penny Keogh
Research Integrity & Development Officer
Email: red.resgov@canterbury.ac.uk

CC Dr Lynn Revell, Supervisor

Research & Enterprise Integrity & Development Office

Canterbury Christ Church University
North Holmes Campus, Canterbury, Kent, CT1 1QU
Tel +44 (0)1227 767700 Fax +44 (0)1227 470442
www.canterbury.ac.uk

Professor Rama Thirunamachandran, Vice Chancellor and Principal

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Registered Charity No: 1098136

Appendix H: Online survey

Understanding how we're using Hegarty Maths to support learning and teaching

As we enter the 3rd year of our use of HM across United Learning secondary schools, we are keen to better understand the ways in which it is used, and how these uses relate to impact. In order to do this, we would really value your candid and honest feedback.

All responses will be treated as anonymously made and the data gathered will not be used for any purpose other than understanding modes of use and links to impact of Hegarty Maths. Research findings will be published in the late Autumn. Your participation is entirely voluntary.

Fay Shepperd (National Director of Maths), Thanos Gidaropoulos (Assistant Principal & PhD candidate, The Totteridge Academy), Michael Davidson (Head of Research and Analysis), Dominic Norrish (Group Director of Technology). Please contact dominic.norrish@unitedlearning.org.uk with any enquiries.

1. Which school do you work at? *

Select your answer

2. Do you consider yourself to be a Maths specialist, or do you have a different subject specialism? *

- I have a degree in a mathematical field
- I have a different subject specialism

3. For how many years have you been teaching Maths? *

- This is my first
- 1-2
- 2-5
- 5-10
- More than 10

4. With 1 being low and 5 being high, how would you describe your confidence in your Maths subject knowledge? *

1 2 3 4 5

5. With 1 being low and 5 being high, how would you rate the efficacy of Hegarty Maths compared to other online learning platforms?

1 2 3 4 5

6. If you have not used any other online learning platforms and are therefore unable to answer Q5, please indicate below.

No comparable experience of other platforms

7. With 1 being low and 5 being high, how would you rate Hegarty Maths as a tool for revision? *

1 2 3 4 5

8. With 1 being low and 5 being high, how would you rate Hegarty Maths videos as tutorials? *

1 2 3 4 5

9. With 1 being low and 5 being high, how would you rate Hegarty Maths quizzes? *

1 2 3 4 5

10. What is your regular practice for setting Hegarty Maths tasks as homework? *

- Daily
- Weekly
- Fortnightly
- Half-termly
- Rarely/Never

11. What is your regular practice for setting differentiated tasks using Hegarty Maths? *

- I generally set tasks for the whole class
- I generally set a variety of tasks for different groups of students
- I generally set bespoke tasks, based on individual students' needs

12. How many tasks do you generally expect your students to complete when Hegarty Maths is set as homework? *

- No expectation
- 1
- 2
- 3
- More than 3

13. How much time do you generally expect your students to spend on Hegarty Maths when it is set as homework? *

- No expectation
- < 30 minutes per week
- 30-60 minutes per week
- 60-90 minutes per week
- > 90 minutes per week

14. Are students directed to watch tutorial videos prior to attempting quizzes? *

- Yes
- No

15. Are students directed to make notes while watching tutorial videos? *

- Yes
- No

16. Do you use Hegarty Maths to consolidate the learning of concepts that you are currently teaching? *

- Never
- Rarely
- Sometimes
- Often
- Always

17. Do you use Hegarty Maths to revise concepts that you have learnt earlier in the year? *

- Never
- Rarely
- Sometimes
- Often
- Always

18. Do you use Hegarty Maths by directing pupils to watch tutorials of concepts they haven't learnt in class yet? *

- Never
- Rarely
- Sometimes
- Often
- Always

19. Do you use Hegarty Maths to target gaps in students' understanding following assessments? *

- Never
- Rarely
- Sometimes
- Often
- Always

Appendix I: Teacher online survey results

ID	Start time	Completion time	Email	Which school do you work at?	Do you consider yourself to be a Maths specialist, or do you have a different subject specialism?	For how many years have you been teaching Maths?	With 1 being low and 5 being high, how would you describe your confidence in your Maths subject knowledge?	With 1 being low and 5 being high, how would you rate the efficacy of Hegarty Maths compared to other online learning platforms?	If you have not used any other online learning platforms and are therefore unable to answer Q5, please indicate below.	With 1 being low and 5 being high, how would you rate Hegarty Maths as a tool for revision?	With 1 being low and 5 being high, how would you rate Hegarty Maths videos as tutorials?	With 1 being low and 5 being high, how would you rate Hegarty Maths quizzes?	What is your regular practice for setting Hegarty Maths tasks as homework?	What is your regular practice for setting differentiated tasks using Hegarty Maths?	How many tasks do you generally expect your students to complete when Hegarty Maths is set as homework?	How much time do you generally expect your students to spend on Hegarty Maths when it is set as homework?	Are students directed to watch tutorial videos prior to attempting quizzes?	Are students directed to make notes while watching tutorial videos?	Do you use Hegarty Maths to consolidate the learning of concepts that you are currently teaching?	Do you use Hegarty Maths to revise concepts that you have learnt earlier in the year?	Do you use Hegarty Maths by directing pupils to watch tutorials of concepts they haven't learnt in class yet?	Do you use Hegarty Maths to target gaps in students' understanding following assessments?
1	7/12/19 14:45:48	7/12/19 14:47:40	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	5		5	4	4	Weekly	I generally set	3	60-90 minutes	Yes	Yes	Often	Often	Rarely	Often
2	7/12/19 14:48:28	7/12/19 14:53:13	anonymous		I have a different subject specialism	5-10	4	5		5	5	4	Half-termly	I generally set	2	30-60 minutes	Yes	Yes	Rarely	Often	Rarely	Always
3	7/12/19 14:51:30	7/12/19 14:54:15	anonymous		I have a degree in a mathematical field	2-5	5	5		4	5	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Sometimes	Always	Never	Often
4	7/12/19 14:54:16	7/12/19 14:56:04	anonymous		I have a degree in a mathematical field	5-10	3	4		4	4	4	Weekly	I generally set	1	30-60 minutes	No	Yes	Rarely	Often	Rarely	Often
5	7/12/19 15:00:07	7/12/19 15:02:00	anonymous		I have a degree in a mathematical field	More than 10	5	3		3	3	4	Weekly	I generally set	1	< 30 minutes	Yes	Yes	Often	Rarely	Rarely	Sometimes
6	7/12/19 14:58:57	7/12/19 15:02:14	anonymous		I have a degree in a mathematical field	2-5	5	5		5	4	5	Weekly	I generally set	1	30-60 minutes	Yes	Yes	Often	Often	Often	Often
7	7/12/19 15:01:12	7/12/19 15:06:17	anonymous		I have a degree in a mathematical field	More than 10	5	5		4	4	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Sometimes	Sometimes	Rarely	Always
8	7/12/19 15:02:30	7/12/19 15:06:51	anonymous		I have a different subject specialism	2-5	5		No comparab	4	5	4	Weekly	I generally set	More than 3	60-90 minutes	Yes	No	Often	Often	Rarely	Often
9	7/12/19 15:10:39	7/12/19 15:12:09	anonymous		I have a degree in a mathematical field	5-10	5	4		4	3	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Sometimes	Sometimes	Sometimes	Sometimes
10	7/12/19 15:11:03	7/12/19 15:12:21	anonymous		I have a degree in a mathematical field	This is my first	5	4		5	4	3	Weekly	I generally set	3	30-60 minutes	Yes	Yes	Often	Often	Often	Rarely
11	7/12/19 15:09:27	7/12/19 15:12:27	anonymous		I have a degree in a mathematical field	More than 10	5	3		4	3	4	Weekly	I generally set	2	60-90 minutes	Yes	Yes	Often	Sometimes	Rarely	Rarely
12	7/12/19 15:11:16	7/12/19 15:13:18	anonymous		I have a degree in a mathematical field	More than 10	5	4		3	5	4	Weekly	I generally set	1	30-60 minutes	Yes	Yes	Often	Often	Sometimes	Always
13	7/12/19 15:13:39	7/12/19 15:15:16	anonymous		I have a degree in a mathematical field	More than 10	5	5		4	3	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Sometimes	Sometimes	Rarely	Often
14	7/12/19 15:18:17	7/12/19 15:20:29	anonymous		I have a degree in a mathematical field	This is my first	5	3		3	2	3	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Often	Often	Rarely	Sometimes
15	7/12/19 15:18:14	7/12/19 15:20:50	anonymous		I have a different subject specialism	2-5	4	4	No comparab	3	5	3	Weekly	I generally set	3	30-60 minutes	No	No	Often	Often	Rarely	Often
16	7/12/19 14:58:57	7/12/19 15:21:27	anonymous		I have a degree in a mathematical field	More than 10	5	5		5	5	5	Half-termly	I generally set	2	< 30 minutes	Yes	No	Often	Often	Sometimes	Always
17	7/12/19 15:19:48	7/12/19 15:21:33	anonymous		I have a degree in a mathematical field	More than 10	4	3		3	3	3	Weekly	I generally set	1	30-60 minutes	Yes	Yes	Often	Often	Sometimes	Often
18	7/12/19 15:31:04	7/12/19 15:35:37	anonymous		I have a different subject specialism	5-10	5	5		3	4	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Often	Often	Never	Sometimes
19	7/12/19 15:36:58	7/12/19 15:39:09	anonymous		I have a different subject specialism	2-5	4	1	No comparab	2	4	3	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Often	Often	Never	Rarely
20	7/12/19 15:43:30	7/12/19 15:45:28	anonymous		I have a degree in a mathematical field	More than 10	5	4		4	4	4	Weekly	I generally set	3	30-60 minutes	Yes	No	Rarely	Rarely	Never	Sometimes
21	7/12/19 15:45:21	7/12/19 15:47:45	anonymous		I have a degree in a mathematical field	More than 10	5	5		5	4	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Often	Sometimes	Sometimes	Always
22	7/12/19 15:58:12	7/12/19 16:01:58	anonymous		I have a degree in a mathematical field	More than 10	4	5		4	5	4	Weekly	I generally set	3	30-60 minutes	Yes	Yes	Often	Sometimes	Rarely	Often
23	7/12/19 16:00:54	7/12/19 16:02:07	anonymous		I have a degree in a mathematical field	This is my first	4	4		3	3	4	Weekly	I generally set	1	30-60 minutes	Yes	Yes	Often	Sometimes	Rarely	Sometimes
24	7/12/19 16:06:57	7/12/19 16:10:58	anonymous		I have a degree in a mathematical field	2-5	5	4	No comparab	4	4	4	Weekly	I generally set	2	> 90 minutes	Yes	Yes	Sometimes	Sometimes	Rarely	Sometimes
25	7/12/19 16:42:44	7/12/19 16:46:16	anonymous		I have a degree in a mathematical field	More than 10	5	5		3	4	4	Weekly	I generally set	2	30-60 minutes	No	No	Often	Sometimes	Sometimes	Always
26	7/12/19 17:06:47	7/12/19 17:08:18	anonymous		I have a degree in a mathematical field	More than 10	5	4		5	3	5	Weekly	I generally set	1	30-60 minutes	Yes	Yes	Sometimes	Often	Rarely	Often
27	7/12/19 17:08:55	7/12/19 17:11:44	anonymous		I have a degree in a mathematical field	More than 10	5	4		4	5	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Sometimes	Often	Often	Always
28	7/12/19 19:35:08	7/12/19 19:37:06	anonymous		I have a degree in a mathematical field	More than 10	5	5		3	4	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Often	Sometimes	Sometimes	Often
29	7/12/19 19:59:56	7/12/19 20:03:26	anonymous		I have a degree in a mathematical field	5-10	4		No comparab	3	4	3	Weekly	I generally set	1	30-60 minutes	Yes	Yes	Often	Sometimes	Never	Often
30	7/12/19 21:18:45	7/12/19 21:21:13	anonymous		I have a degree in a mathematical field	5-10	5	5		4	5	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Often	Often	Rarely	Sometimes
31	7/13/19 11:23:23	7/13/19 11:26:34	anonymous		I have a degree in a mathematical field	More than 10	4	5		4	4	4	Weekly	I generally set	1	30-60 minutes	Yes	Yes	Often	Sometimes	Sometimes	Rarely
32	7/13/19 18:43:13	7/13/19 18:46:24	anonymous		I have a different subject specialism	This is my first	4	4	No comparab	4	5	5	Weekly	I generally set	1	30-60 minutes	Yes	No	Always	Sometimes	Never	Sometimes
33	7/14/19 5:47:57	7/14/19 5:50:50	anonymous		I have a different subject specialism	5-10	3	3		4	4	4	Weekly	I generally set	3	30-60 minutes	Yes	No	Often	Often	Sometimes	Often
34	7/14/19 10:05:37	7/14/19 10:07:37	anonymous		I have a different subject specialism	1-2	3	4		4	5	5	Weekly	I generally set	3	30-60 minutes	Yes	Yes	Sometimes	Always	Often	Often
35	7/14/19 10:29:53	7/14/19 10:36:13	anonymous		I have a degree in a mathematical field	5-10	5	4		3	2	3	Weekly	I generally set	More than 3	30-60 minutes	No	Yes	Rarely	Rarely	Sometimes	Sometimes
36	7/14/19 12:06:15	7/14/19 12:10:51	anonymous		I have a degree in a mathematical field	More than 10	5	4		4	4	4	Weekly	I generally set	1	30-60 minutes	Yes	Yes	Sometimes	Often	Rarely	Often
37	7/14/19 12:19:28	7/14/19 12:25:42	anonymous		I have a degree in a mathematical field	More than 10	5	4		4	4	3	Weekly	I generally set	2	30-60 minutes	No	Yes	Often	Sometimes	Rarely	Sometimes
38	7/14/19 14:16:22	7/14/19 14:19:28	anonymous		I have a degree in a mathematical field	More than 10	5	4		4	4	3	Half-termly	I generally set	1	30-60 minutes	Yes	Yes	Often	Rarely	Sometimes	Often
39	7/14/19 16:10:15	7/14/19 16:13:29	anonymous		I have a degree in a mathematical field	1-2	4		No comparab	3	4	4	Weekly	I generally set	3	60-90 minutes	Yes	Yes	Sometimes	Often	Rarely	Often
40	7/14/19 17:40:51	7/14/19 17:44:42	anonymous		I have a degree in a mathematical field	1-2	4	1	No comparab	5	5	5	Weekly	I generally set	1	30-60 minutes	Yes	Yes	Sometimes	Sometimes	Sometimes	Sometimes
41	7/14/19 20:18:16	7/14/19 20:20:51	anonymous		I have a different subject specialism	5-10	4	4		4	4	4	Weekly	I generally set	1	30-60 minutes	Yes	Yes	Sometimes	Sometimes	Sometimes	Sometimes
42	7/14/19 22:39:21	7/14/19 22:41:18	anonymous		I have a degree in a mathematical field	More than 10	5	4		4	3	4	Weekly	I generally set	1	30-60 minutes	Yes	No	Often	Often	Rarely	Rarely
43	7/15/19 7:02:21	7/15/19 7:03:26	anonymous		I have a degree in a mathematical field	1-2	5	5		5	5	5	Weekly	I generally set	2	30-60 minutes	Yes	No	Always	Always	Sometimes	Sometimes
44	7/15/19 7:08:07	7/15/19 7:10:31	anonymous		I have a different subject specialism	More than 10	5	5	No comparab	5	5	5	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Always	Often	Always	Always
45	7/15/19 7:28:35	7/15/19 7:32:37	anonymous		I have a degree in a mathematical field	More than 10	5	5		5	5	5	Weekly	I generally set	1	< 30 minutes	Yes	Yes	Sometimes	Sometimes	Rarely	Always
46	7/15/19 7:48:36	7/15/19 7:50:17	anonymous		I have a degree in a mathematical field	More than 10	5	3		2	3	3	Weekly	I generally set	1	30-60 minutes	Yes	Yes	Sometimes	Sometimes	Sometimes	Sometimes
47	7/15/19 7:55:38	7/15/19 7:58:05	anonymous		I have a different subject specialism	More than 10	4	5		4	5	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Sometimes	Often	Never	Sometimes
48	7/15/19 8:29:12	7/15/19 8:30:53	anonymous		I have a degree in a mathematical field	5-10	4	4		5	5	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Sometimes	Sometimes	Sometimes	Often
49	7/15/19 8:35:46	7/15/19 8:37:03	anonymous		I have a different subject specialism	5-10	3	4		4	4	3	Weekly	I generally set	2	30-60 minutes	Yes	No	Often	Often	Rarely	Often
50	7/15/19 8:45:25	7/15/19 8:49:52	anonymous		I have a degree in a mathematical field	5-10	5	4		4	4	4	Weekly	I generally set	3	30-60 minutes	Yes	Yes	Often	Sometimes	Sometimes	Always
51	7/15/19 8:43:23	7/15/19 8:51:28	anonymous		I have a degree in a mathematical field	5-10	5	4		4	3	3	Half-termly	I generally set	3	60-90 minutes	Yes	No	Sometimes	Sometimes	Never	Often
52	7/15/19 8:51:23	7/15/19 8:52:59	anonymous		I have a degree in a mathematical field	More than 10	5	4		4	4	4	Weekly	I generally set	2	30-60 minutes	Yes	Yes	Sometimes	Sometimes	Sometimes	Often
53	7/15/19 8:48:35	7/15/19 8:55:13	anonymous		I have a degree in a mathematical field	This is my first	4	4	No comparab	2	2	3	Weekly	I generally set	More than 3	60-90 minutes	No	Yes	Sometimes	Sometimes	Always	Often

ID	Start time	Completion tim	Email	Which school do you work at?	Do you consider yourself to be a Maths specialist, or do you have a different subject specialism?	For how many years have you been teaching Maths?	With 1 being low and 5 being high, how would you describe your confidence in your Maths subject owledge?	With 1 being low and 5 being high, how would you rate the efficacy of Hegarty Maths compared to other line learning platforms?	If you have not used any other online learning platforms and are therefore unable to answer Q5, please indicate low.	With 1 being low and 5 being high, how would you rate Hegarty Maths as a tool for revision?	With 1 being low and 5 being high, how would you rate Hegarty Maths videos as tutorials?	With 1 being low and 5 being high, how would you rate Hegarty Maths quizzes?	What is your regular practice for setting Hegarty Maths tasks as homework?	What is your regular practice for setting differentiated tasks using Hegarty Maths?	How many tasks do you generally expect your students to complete when Hegarty Maths is set as mework?	How much time do you generally expect your students to spend on Hegarty Maths when it is set as mework?	Are students directed to watch tutorial videos prior to attempting quizzes?	Are students directed to make notes while watching tutorial videos?	Do you use Hegarty Maths to consolidate the learning of concepts that you are currently teaching?	Do you use Hegarty Maths to revise concepts that you have learnt earlier in the year?	Do you use Hegarty Maths by directing pupils to watch tutorials of concepts they haven't learnt in class t?	Do you use Hegarty Maths to target gaps in students' understanding following assessments?
53	7/15/19 8:48:35	7/15/19 8:55:13	anonymous	[redacted]	I have a degree in a mathematical field	This is my first	4	4	No comparab	2	2	3	Weekly	I generally set	More than 3	60-90 minute	No	Yes	Sometimes	Sometimes	Always	Often
54	7/15/19 8:45:36	7/15/19 8:55:47	anonymous	[redacted]	I have a different subject specialism	5-10	4	5		4	5	4	Weekly	I generally set	More than 3	60-90 minute	Yes	Yes	Often	Often	Rarely	Always
55	7/15/19 8:57:29	7/15/19 8:59:10	anonymous	[redacted]	I have a different subject specialism	2-5	4	3		3	3	3	Weekly	I generally set	3	No expectatio	Yes	Yes	Never	Often	Rarely	Sometimes
56	7/15/19 9:01:57	7/15/19 9:03:23	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	3		4	3	3	Weekly	I generally set	2	30-60 minute	Yes	Yes	Sometimes	Often	Rarely	Often
57	7/15/19 9:04:13	7/15/19 9:06:06	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	3		4	4	2	Weekly	I generally set	3	30-60 minute	Yes	No	Sometimes	Sometimes	Never	Always
58	7/15/19 9:11:37	7/15/19 9:13:54	anonymous	[redacted]	I have a degree in a mathematical field	2-5	5	4		4	4	4	Weekly	I generally set	More than 3	60-90 minute	No	No	Sometimes	Always	Often	Often
59	7/15/19 9:42:55	7/15/19 9:44:26	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	4	4		5	4	4	Weekly	I generally set	2	30-60 minute	Yes	No	Often	Often	Often	Often
60	7/15/19 9:52:50	7/15/19 9:56:06	anonymous	[redacted]	I have a different subject specialism	2-5	3	5		5	5	4	Weekly	I generally set	1	< 30 minutes	Yes	Yes	Always	Sometimes	Rarely	Never
61	7/15/19 9:56:27	7/15/19 9:58:02	anonymous	[redacted]	I have a different subject specialism	More than 10	5	4		5	4	4	Weekly	I generally set	1	< 30 minutes	Yes	Yes	Rarely	Sometimes	Rarely	Always
62	7/15/19 10:04:34	7/15/19 10:08:11	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	4		4	4	5	Weekly	I generally set	2	60-90 minute	Yes	No	Often	Sometimes	Sometimes	Sometimes
63	7/15/19 10:05:43	7/15/19 10:08:11	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	5		5	5	5	Weekly	I generally set	2	30-60 minute	Yes	Yes	Sometimes	Often	Often	Often
64	7/15/19 10:15:18	7/15/19 10:17:51	anonymous	[redacted]	I have a different subject specialism	5-10	5			3	3	2	Daily	I generally set	3	60-90 minute	Yes	Yes	Often	Sometimes	Never	Always
65	7/15/19 10:57:57	7/15/19 11:00:34	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	4		3	3	4	Weekly	I generally set	2	30-60 minute	Yes	Yes	Always	Often	Rarely	Often
66	7/15/19 10:24:03	7/15/19 11:16:21	anonymous	[redacted]	I have a different subject specialism	1-2	3	3		4	4	3	Weekly	I generally set	1	< 30 minutes	Yes	Yes	Never	Sometimes	Never	Rarely
67	7/15/19 12:00:49	7/15/19 12:03:06	anonymous	[redacted]	I have a degree in a mathematical field	1-2	5	3		4	4	4	Weekly	I generally set	1	30-60 minute	Yes	Yes	Sometimes	Rarely	Never	Never
68	7/15/19 12:27:09	7/15/19 12:29:03	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	4		5	4	4	Weekly	I generally set	1	60-90 minute	Yes	Yes	Sometimes	Often	Rarely	Often
69	7/15/19 12:50:09	7/15/19 12:56:57	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	4		4	4	4	Weekly	I generally set	1	60-90 minute	Yes	Yes	Often	Sometimes	Never	Often
70	7/15/19 13:09:42	7/15/19 13:11:32	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	4		4	5	3	Weekly	I generally set	2	< 30 minutes	Yes	No	Sometimes	Sometimes	Sometimes	Sometimes
71	7/15/19 13:15:23	7/15/19 13:17:54	anonymous	[redacted]	I have a degree in a mathematical field	This is my first	5	5		4	5	5	Weekly	I generally set	1	< 30 minutes	Yes	Yes	Sometimes	Often	Never	Sometimes
72	7/15/19 13:41:39	7/15/19 13:43:01	anonymous	[redacted]	I have a degree in a mathematical field	2-5	5	4		4	4	4	Weekly	I generally set	2	30-60 minute	Yes	Yes	Often	Often	Rarely	Often
73	7/15/19 14:28:55	7/15/19 14:30:32	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	3		4	3	3	Rarely/Never	I generally set	3	30-60 minute	Yes	Yes	Sometimes	Sometimes	Never	Sometimes
74	7/15/19 14:57:37	7/15/19 14:59:12	anonymous	[redacted]	I have a different subject specialism	2-5	4	4	No comparab	5	5	5	Weekly	I generally set	1	< 30 minutes	Yes	Yes	Always	Sometimes	Never	Rarely
75	7/16/19 8:18:36	7/16/19 8:20:48	anonymous	[redacted]	I have a degree in a mathematical field	5-10	4	4		4	4	4	Weekly	I generally set	3	30-60 minute	Yes	Yes	Often	Sometimes	Rarely	Often
76	7/16/19 8:32:02	7/16/19 8:34:13	anonymous	[redacted]	I have a degree in a mathematical field	2-5	5	4		5	2	3	Weekly	I generally set	1	30-60 minute	Yes	Yes	Often	Sometimes	Rarely	Often
77	7/16/19 8:37:34	7/16/19 8:39:23	anonymous	[redacted]	I have a degree in a mathematical field	2-5	5	4	No comparab	4	2	3	Weekly	I generally set	2	30-60 minute	Yes	Yes	Always	Often	Rarely	Sometimes
78	7/16/19 8:50:49	7/16/19 8:52:44	anonymous	[redacted]	I have a different subject specialism	2-5	4	3		4	2	3	Weekly	I generally set	1	< 30 minutes	Yes	No	Always	Often	Never	Rarely
79	7/16/19 9:56:43	7/16/19 9:58:36	anonymous	[redacted]	I have a different subject specialism	More than 10	4	5		4	5	5	Weekly	I generally set	2	30-60 minute	Yes	Yes	Always	Rarely	Sometimes	Often
80	7/16/19 12:12:43	7/16/19 12:15:27	anonymous	[redacted]	I have a different subject specialism	5-10	2	3		4	4	4	Weekly	I generally set	2	30-60 minute	Yes	Yes	Sometimes	Sometimes	Rarely	Often
81	7/16/19 12:41:22	7/16/19 12:42:53	anonymous	[redacted]	I have a degree in a mathematical field	1-2	4	5		3	3	4	Weekly	I generally set	1	< 30 minutes	No	No	Always	Rarely	Rarely	Often
82	7/16/19 14:57:59	7/16/19 14:58:58	anonymous	[redacted]	I have a different subject specialism	1-2	3	4	No comparab	4	5	5	Weekly	I generally set	3	60-90 minute	Yes	Yes	Often	Always	Rarely	Sometimes
83	7/16/19 15:05:03	7/16/19 15:06:54	anonymous	[redacted]	I have a degree in a mathematical field	2-5	5	4		5	5	3	Weekly	I generally set	3	30-60 minute	Yes	Yes	Often	Often	Sometimes	Often
84	7/17/19 11:08:37	7/17/19 11:21:32	anonymous	[redacted]	I have a degree in a mathematical field	5-10	4	4		5	4	4	Weekly	I generally set	2	30-60 minute	Yes	No	Sometimes	Often	Rarely	Often
85	7/17/19 12:57:15	7/17/19 12:59:27	anonymous	[redacted]	I have a degree in a mathematical field	5-10	4	5		4	5	4	Weekly	I generally set	1	30-60 minute	No	Yes	Never	Often	Rarely	Always
86	7/17/19 14:33:41	7/17/19 14:55:27	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	4		4	4	4	Weekly	I generally set	2	30-60 minute	Yes	No	Always	Often	Sometimes	Sometimes
87	7/17/19 15:09:39	7/17/19 15:11:17	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	4	4		5	4	4	Weekly	I generally set	1	30-60 minute	Yes	Yes	Often	Sometimes	Rarely	Often
88	7/18/19 11:02:49	7/18/19 11:05:33	anonymous	[redacted]	I have a different subject specialism	5-10	5	5		5	5	5	Weekly	I generally set	More than 3	60-90 minute	Yes	Yes	Often	Often	Rarely	Often
89	7/18/19 11:04:40	7/18/19 11:06:19	anonymous	[redacted]	I have a different subject specialism	5-10	4	5		5	4	4	Weekly	I generally set	More than 3	60-90 minute	Yes	Yes	Often	Often	Rarely	Often
90	7/18/19 11:05:12	7/18/19 11:06:52	anonymous	[redacted]	I have a degree in a mathematical field	2-5	5		No comparab	4	4	4	Weekly	I generally set	1	30-60 minute	Yes	Yes	Often	Often	Rarely	Often
91	7/18/19 11:07:47	7/18/19 11:10:52	anonymous	[redacted]	I have a degree in a mathematical field	This is my first	5	5		4	4	4	Weekly	I generally set	More than 3	30-60 minute	Yes	Yes	Often	Often	Rarely	Sometimes
92	7/18/19 11:10:55	7/18/19 11:12:10	anonymous	[redacted]	I have a degree in a mathematical field	This is my first	5	5		4	4	4	Weekly	I generally set	More than 3	30-60 minute	Yes	Yes	Often	Often	Rarely	Sometimes
93	7/18/19 11:10:11	7/18/19 11:12:56	anonymous	[redacted]	I have a degree in a mathematical field	5-10	5	5		4	4	5	Weekly	I generally set	More than 3	60-90 minute	Yes	Yes	Often	Often	Rarely	Often
94	7/18/19 11:11:29	7/18/19 11:13:36	anonymous	[redacted]	I have a different subject specialism	2-5	4	5		5	4	5	Weekly	I generally set	More than 3	60-90 minute	Yes	Yes	Always	Often	Rarely	Often
95	7/18/19 11:32:50	7/18/19 11:34:03	anonymous	[redacted]	I have a different subject specialism	This is my first	4		No comparab	4	3	4	Weekly	I generally set	More than 3	60-90 minute	Yes	Yes	Often	Often	Often	Often
96	7/18/19 11:57:44	7/18/19 11:59:32	anonymous	[redacted]	I have a different subject specialism	1-2	5	4	No comparab	5	4	5	Weekly	I generally set	More than 3	60-90 minute	Yes	Yes	Always	Often	Sometimes	Sometimes
97	7/18/19 12:39:01	7/18/19 12:45:04	anonymous	[redacted]	I have a degree in a mathematical field	1-2	3	5	No comparab	3	3	3	Weekly	I generally set	2	30-60 minute	Yes	No	Often	Sometimes	Rarely	Often
98	7/18/19 12:05:45	7/18/19 12:50:20	anonymous	[redacted]	I have a different subject specialism	This is my first	4	5	No comparab	4	4	4	Weekly	I generally set	More than 3	30-60 minute	Yes	Yes	Often	Often	Sometimes	Sometimes
99	7/18/19 15:18:09	7/18/19 15:20:32	anonymous	[redacted]	I have a different subject specialism	2-5	4	4	No comparab	4	4	4	Weekly	I generally set	More than 3	60-90 minute	Yes	Yes	Sometimes	Sometimes	Never	Sometimes
100	7/19/19 8:19:16	7/19/19 8:21:14	anonymous	[redacted]	I have a degree in a mathematical field	5-10	5	5	No comparab	5	5	5	Weekly	I generally set	2	30-60 minute	Yes	Yes	Often	Often	Often	Often
101	7/19/19 8:18:40	7/19/19 8:23:46	anonymous	[redacted]	I have a degree in a mathematical field	1-2	5	5		5	5	5	Weekly	I generally set	2	60-90 minute	Yes	No	Often	Often	Always	Sometimes
102	7/19/19 8:25:15	7/19/19 8:29:10	anonymous	[redacted]	I have a degree in a mathematical field	5-10	5	4		5	4	4	Weekly	I generally set	No expectatio	< 30 minutes	Yes	No	Often	Never	Never	Rarely
103	7/19/19 12:30:30	7/19/19 12:31:37	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	5	5		4	4	5	Weekly	I generally set	1	30-60 minute	Yes	Yes	Sometimes	Sometimes	Sometimes	Sometimes
104	7/21/19 9:11:07	7/21/19 9:15:51	anonymous	[redacted]	I have a different subject specialism	More than 10	4	4		5	4	4	Weekly	I generally set	2	60-90 minute	Yes	Yes	Sometimes	Sometimes	Often	Often
105	8/30/19 19:18:37	8/30/19 19:27:21	anonymous	[redacted]	I have a degree in a mathematical field	More than 10	4	3		4	4	3	Half-termly	I generally set	More than 3	30-60 minute	Yes	No	Sometimes	Often	Never	Always
106	9/1/19 23:51:14	9/1/19 23:53:10	anonymous	[redacted]	I have a different subject specialism	2-5	4	4		5	4	3	Weekly	I generally set	2	30-60 minute	Yes	No	Often	Often	Rarely	Always

Appendix J: Pearson correlation calculations

Excel formulas used to calculate the Pearson correlation coefficient, *r*, and associated probability value, *p*.

Question	1Q1	1Q2	1Q3	1Q4
Description	Types of angles	Solve 1-step equations	Adding and subtracting positive and negative numbers	Linking multiplying/dividing fractions & whole numbers
Total Marks	1	1	1	1
AO category	**1**	**1**	**1**	**2**
HM clip 1	455	178	41	72
HM clip 2				
HM clip 3				
HM clip 4				
[redacted]	34.43536121673	268.492395437262	66.2528517110266	20.9980988593156
	27.7567010309278	290.810309278351	56.4886597938144	4.97731958762887
	8.84444444444444	285.82962962963	104.65037037037	61.357037037037
	33.9599578503688	217.906217070601	116.110642781876	13.4699683877766
	14.7815491731941	180.508268059182	59.7815491731941	2.37771975630983
	47.096511627907	492.197674418605	184.672093023256	51.5174418604651
	30.1977309562399	222.698541329011	73.6110210696921	7.81037277147488
	3.81602002503129	122.623279098874	27.5081351689612	3.55944931163955
PEARSON	=PEARSON(B11:B17,Marks!B13:B19)	=PEARSON(C11:C17,Marks!C13:C19)	=PEARSON(D11:D17,Marks!D13:D19)	=PEARSON(E11:E17,Marks!E13:E19)
N	=COUNT(B11:B17)	=COUNT(C11:C17)	=COUNT(D11:D17)	=COUNT(E11:E17)
T STATISTIC	=(B20*(SQRT(B21-2)))/(SQRT(1-B20^2))	=(C20*(SQRT(C21-2)))/(SQRT(1-C20^2))	=(D20*(SQRT(D21-2)))/(SQRT(1-D20^2))	=(E20*(SQRT(E21-2)))/(SQRT(1-E20^2))
T STATISTIC +	=ABS(B22)	=ABS(C22)	=ABS(D22)	=ABS(E22)
DF	=B21-2	=C21-2	=D21-2	=E21-2
p VALUE	=TDIST(B23,B24,2)	=TDIST(C23,C24,2)	=TDIST(D23,D24,2)	=TDIST(E23,E24,2)

Appendix K: T-test calculations

Excel formulas used to calculate t-test values

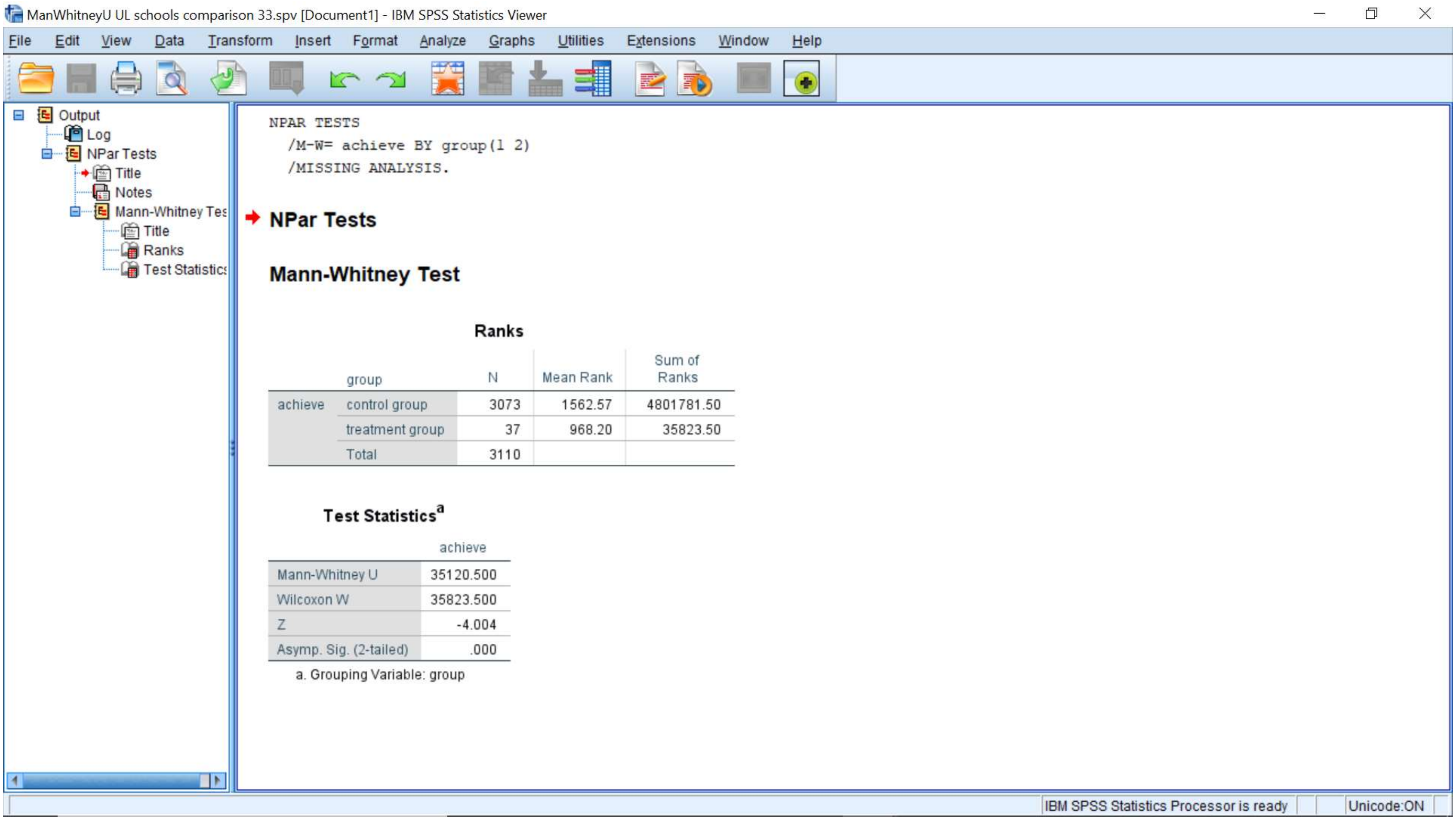
HM	SCHNAME	ATT8SCRMAT	P8MEA		
HM	School name	Average Attainment 8 score per pupil for mathematics element	Progress 8 measure after adjustment for extreme scores		TRUE
		1.508900299	0.45493158	71.3384073	
		1.508154611	0.45470676	71.3031524	
1012	HM schools	9.073774687	0.00	495.99	0.00303221
2098	Non HM scho	9.374642995	0.01	8659.26	0.02596604
		1.933156189	0.45732761	70.9141638	
		1.933617068	0.45743664	70.9310702	
3110	Totals in redu	9.275852565	0.00		0.02
	Totals All sch	9.1	-0.03		
	HM - nonHM	-0.300868308			-0.0229338
	Difference	0.300868308			0.02293384
	Pooled SD	1.805917083			0.45647673
	Standard erro	0.06911702			0.01747052
		-4.353027799			-1.3127164
	T-statistic	4.353027799			1.31271637
	DF	3108			3108
	P	0.00139%			18.93755%

:

HM	SCHNAME	ATT8SCRMAT	P8MEA		
HM	School name	Average Attainment 8 score per pupil for mathematics element	Progress 8 measure after adjustment for extreme scores		TRUE
		1.50890029903879	0.4549315831	71.338407325	
		1.5081546106814	0.4547067590	71.303152365	
1012	HM schools	9.07377468696808	-0.0008102766	495.98999999	0.00303220560724809
2098	Non HM schools	9.37464299454268	0.0050619637	8659.26	0.0259660433484065
		1.93315618890375	0.4573276094	70.914163784	
		1.93361706772515	0.4574366397	70.931070248	
3110	Totals in reduced data	9.27585256472831	0.0031511254		0.0184188766703282
	Totals All schools	9.1	-0.03		
	HM - nonHM	=AI7-AI8			=AO7-AO8
	Difference	=ABS(AI26)			=ABS(AO26)
	Pooled SD	=SQRT(((($C$7-1)*AI6^2)+(($C$8-1)*AI9^2))/($C$7+$C$8-2))			=SQRT(((($C$7-1)*AM6^2)+(($C$8-1)*AM9^2))/($C$7+$C$8-2))
	Standard error	=AI28*SQRT((1/$C$7)+(1/$C$8))			=AO28*SQRT((1/$C$7)+(1/$C$8))
		=(AI7-AI8)/AI29			=(AO7-AO8)/AO29
	T-statistic	=ABS(AI30)			=ABS(AO30)
	DF	=$C$7+$C$8-2			=$C$7+$C$8-2
	P	=TDIST(AI31,AI32,2)			=TDIST(AO31,AO32,2)

Appendix L: Mann-Whitney *U* calculations (SPSS)

SPSS screenshots to show how Mann-Whitney *U* test statistics were calculated:



Ranks

	group	N	Mean Rank	Sum of Ranks
achieve	control group	3073	1562.57	4801781.50
	treatment group	37	968.20	35823.50
	Total	3110		

Test Statistics[a]

	achieve
Mann-Whitney U	35120.500
Wilcoxon W	35823.500
Z	-4.004
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: group

Appendix M: Mann-Whitney *U* calculations (Microsoft Excel)

Excel screenshots to show how Mann-Whitney *U* test statistics were calculated:

UL	SCHNAME	ATT8SCRN	P8MEAM/	ATT8SCRN	P8MEAM/	ATT8SCRN	P8MEAM/	ATT8SCRN	ATT8SCRN	ATT8SCRN
UL		Average Attainment 8 score per pupil for mathematics element	Progress 8 measure for mathematics element	Average Attainment 8 score per disadvantaged pupil for mathematics element	Progress 8 measure for maths element - disadvantaged pupils	Average Attainment 8 score per non-disadvantaged pupil for mathematics element	Progress 8 measure for maths element - non-disadvantaged pupils	Average Attainment 8 score per pupil for whom English is an additional language for mathematics element	Average Attainment 8 score per girl for mathematics element	Average Attainment 8 score per boy for mathematics element
37	UL schools	8.816	0.122	7.578	-0.116	9.308	0.276	9.259	8.644	8.680
3073	Non UL schools	9.176	-0.008	7.550	-0.323	9.623	0.098	9.630	8.997	9.079
	Mann-Whitney U	49550	48534.5	51734	43210	48262.5	44116.5	31314	45096.5	44054.5
	Wilcoxon W	50253	4771735.5	4604387	4586815	48928.5	4599787.5	31875	45762.5	44684.5
	Z-score	-1.345	-1.532	-0.489	-2.102	-1.156	-1.941	-1.005	-1.418	-1.208
	p-value	0.179	0.126	0.625	0.036	0.248	0.052	0.315	0.156	0.227
	r	0.024	0.027	0.009	0.038	0.021	0.035	0.022	0.026	0.022
		-0.024	-0.027	-0.009	-0.038	-0.021	-0.035	-0.022	-0.026	-0.022

The Mann–Whitney *U* and Wilcoxon W test statistics were calculated in SPSS and transferred to Excel.

The formulas used to calculate the z–score and r value were:

z	=NORM.S.INV(AG3149)
r	=NORM.S.INV(AG3149)/SQRT(COUNT(AG4:AG40)+COUNT(AG41:AG3113))

Appendix N: Chi-square test calculations

Excel screenshots to show how chi-square test statistics were calculated:

HM	SCHNAI	SCHNAI	NFTYPE	TOTPUPS	TPUP	NUMGIRLS	PBPUP	GPUP	PGPUP	KS2APS		
UL	School name	School now known as (used if the school has converted to an academy on or after 12 Sept 2018)		Number of pupils on roll (all ages)	Number of pupils at the end of key stage 4	Number of boys at the end of key stage 4	Percentage of pupils at the end of key stage 4 who are boys	Number of girls at the end of key stage 4	Percentage of pupils at the end key stage 4 who are girls	Key stage 2 Average Points Score of the cohort at the end of key stage 4	#	TRUE
			STDEV.s	370.981846	48.84465	33.39278482	0.159043736	30.21646	0.159043736	1.38218502	1425.918667	
			STDEV.p	365.934239	48.18007	32.93844005	0.156879775	29.80533	0.156879775	1.36337891	1406.517509	
37	UL			34426	5337	2692	50.44%	2645	49.56%	27.9891892	149903.2	28.0875
3073	Non-UL			3147329	517116	260179	50.31%	256937	49.69%	28.7709079	14928509.8	28.8688
			STDEV.p	394.28756	61.68744	42.16342557	0.182277058	41.8669	0.182276405	1.46061864	1825.053564	
			STDEV.s	394.351729	61.69748	42.17028755	0.182306723	41.87371	0.18230607	1.46085636	1825.350587	
3110	Totals in reduced data			3181755	522453	262871	50%	259582	50%	28.8	15078413	
						Boys	Girls	Totals		Low Prior	Non-Low prior	Totals
					HM	2692	2645	5337		659	4678	5337
					non HM	260179	256937	517116		50765	466351	517116
						262871	259582	522453		51424	471029	522453
					HM	2685.299016	2651.700984			525.3101963	4811.689804	
					non HM	260185.701	256930.299			50898.6898	466217.3102	
						Chi - squared	p	phi		Chi - squared	p	phi
						0.034002932	85.37006%	0.0002551		38.12760918	0.00000%	0.008543

Here are the formulas used to calculate the chi-square statistics above:

	Boys	Girls	Totals
HM	=I7	=K7	=SUM(I17:J17)
non HM	=I8	=K8	=SUM(I18:J18)
	=SUM(I17:I18)	=SUM(J17:J18)	=SUM(K17:K18)
HM	=I19*K17/K19	=J19*K17/K19	
non HM	=I19*K18/K19	=J19*K18/K19	
	Chi - squared	p	phi
	=((I17-I21)^2/I21)+((J17-J21)^2/J21)+((I18-I22)^2/I22)+((J18-J22)^2/J22)	=CHITEST(I17:J18,I21:J22)	=SQRT(I24/K19)

	Low Prior	Non-Low prior	Totals
HM	=P7	=O17-M17	=$H$7
non HM	=P8	=O18-M18	=$H$8
	=SUM(M17:M18)	=SUM(N17:N18)	=SUM(O17:O18)
HM	=M$19*$O17/$O$19	=N$19*$O17/$O$19	
non HM	=M$19*$O18/$O$19	=N$19*$O18/$O$19	
	Chi - squared	p	phi
	=((M17-M21)^2/M21)+((N17-N21)^2/N21)+((M18-M22)^2/M22)+((N18-N22)^2/N22)	=CHITEST(M17:N18,M21:N22)	=SQRT(M24/O19)

Appendix O: Question-by-question analysis - AQA GCSE statistically significant results

Below is a short summary and description of the statistically significant results seen when correlating GCSE performance on the Summer 2019 AQA Mathematics Examinations with time spent on the associated Hegartymaths clips.

1) **Foundation Paper 2 (Calculator), Q20 – Loci. Hegartymaths clips associated: 677 – Loci (4).**
   Assessment Objective: 1, Total marks: 3, AQA average marks: 0.21 (7%), UL Schools average: 0.20 (6.7%). Strong negative correlation observed (*r*=-.852, *p*=.015).

2) **Foundation Paper 3 (Calculator), Q24 – Density. Hegartymaths clips associated: 725 – Density (1); 729 – Density (5).**
   Assessment Objective: 1, Total marks: 3, AQA average marks: 0.75 (25%), UL Schools average: 0.85 (28%). Strong negative correlation observed (*r*=-.797, *p*=.032).

3) **Higher Paper 1 (Non-Calculator), Q14 – Interior angle in quadrilaterals, share in a given ratio. Hegartymaths clips associated: 332 – Share in a given ratio 1; 333 – Share in a given ratio 2; 560 – Interior angles in quadrilaterals.**
   Assessment Objective: 2, Total marks: 3, AQA average marks: 1.97 (66%), UL Schools average: 2.18 (73%). Strong negative correlation observed (*r*=-.714, *p*=.047).

4) **Higher Paper 1 (Non-Calculator), Q15b – Drawing cumulative frequency diagrams. Hegartymaths clips associated: 437 – Cumulative frequency diagrams (1).**
   Assessment Objective: 1, Total marks: 2, AQA average marks: 1.22 (0.61%), UL Schools average: 1.09 (54.5%). Strong positive correlation observed (*r*=.821, *p*=.012).

5) **Higher Paper 1 (Non-Calculator), Q15c – Interpreting cumulative frequency diagrams. Hegartymaths clips associated: 438 – Cumulative frequency diagrams (2).**
   Assessment Objective: 1, Total marks: 2, AQA average marks: 1.43 (71.5%), UL Schools average: 1.37 (68.5%). Strong positive correlation observed (*r*=.745, *p*=.033).

6) **Higher Paper 2 (Calculator), Q5 – Loci. Hegartymaths clips associated: 677 – Loci (4).**
   Assessment Objective: 1, Total marks: 3, AQA average marks: 1.14 (38%), UL Schools average: 1.04 (34.7%). Strong positive correlation observed (*r*=.792, *p*=.019).

7) **Higher Paper 2 (Calculator), Q12 – Experimental probability and relative frequency. Hegartymaths clips associated: 356 – Experimental probability and relative frequency.**
   Assessment Objective: 2, Total marks: 1, AQA average marks: 0.26 (26%), UL Schools average: 0.26 (26%). Strong positive correlation observed (*r*=.729, *p*=.040).

8) **Higher Paper 3 (Calculator), Q19 – Critique box plots. Hegartymaths clips associated: 435 – Box plots (2).**
   Assessment Objective: 2, Total marks: 2, AQA average marks: 1.15 (57.5%), UL Schools average: 1.14 (57%). Strong positive correlation observed (*r*=.875, *p*=.004).

9) **Higher Paper 3 (Calculator), Q22b – Interpreting Venn diagrams for probability. Hegartymaths clips associated: 383 – Venn diagrams for probability (1).**
   Assessment Objective: 2, Total marks: 2, AQA average marks: 0.79 (39.5%), UL Schools average: 0.76 (38%). Strong positive correlation observed (*r*=.750, *p*=.032).

Appendix P: Question-by-question analysis - Edexcel GCSE statistically significant results

Below is a short summary and description of the statistically significant results seen when correlating GCSE performance on the Summer 2019 AQA Mathematics Examinations with time spent on the associated Hegartymaths clips.

1) **Foundation Paper 1 (Non-Calculator), Q6 – Apply four operations. Hegartymaths clips associated: 752 – Money (problem solving 1).**
   Assessment Objective: 1, Total marks: 4, EDEXCEL average marks: 3.33 (83.3%), UL Schools average: 3.32 (83.0%).
   Strong negative correlation observed (*r*=-.534, *p*=.003).

2) **Foundation Paper 1 (Non-Calculator), Q9b – Change between standard units and compound units. Hegartymaths clips associated: 721 – Speed (6).**
   Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 1.45 (72.5%), UL Schools average: 1.42 (70.8%).
   Strong negative correlation observed (*r*=-.497, *p*=.006).

3) **Foundation Paper 1 (Non-Calculator), Q10c – Solve linear equations. Hegartymaths clips associated: Solve 2-step equations (involving multiplication).**
   Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 1.64 (82.0%), UL Schools average: 1.72 (86.2%).
   Strong positive correlation observed (*r*=.576, *p*=.001).

4) **Foundation Paper 1 (Non-Calculator), Q12bii – Properties of angles. Hegartymaths clips associated: 812 – Angles around a point (1).**
   Assessment Objective: 1, Total marks: 1, EDEXCEL average marks: 0.69 (69.0%), UL Schools average: 0.70 (69.7%).
   Medium positive correlation observed (*r*=.428, *p*=.020).

5) **Foundation Paper 1 (Non-Calculator), Q14b – Calculate exactly with fractions. Hegartymaths clips associated: 72 – Linking multiplying/dividing fractions and whole numbers.**
   Assessment Objective: 2, Total marks: 1, EDEXCEL average marks: 0.12 (12.0%), UL Schools average: 0.17 (17.4%).
   Strong positive correlation observed (*r*=.558, *p*=.002).

6) **Foundation Paper 1 (Non-Calculator), Q16b – Factorise simple expressions. Hegartymaths clips associated: 437 – Factorise simple expressions 1.**
   Assessment Objective: 1, Total marks: 1, EDEXCEL average marks: 0.5 (50.0%), UL Schools average: 0.66 (66.0%).
   Medium positive correlation observed (*r*=.404, *p*=.030).

7) **Foundation Paper 1 (Non-Calculator), Q26 – Combinations of transformations. Hegartymaths clips associated: 639 – Reflections (1); 650 – Describe transformations (1).**
   Assessment Objective: 1, Total marks: 3, EDEXCEL average marks: 0.59 (19.7%), UL Schools average: 0.68 (22.7%).
   Medium positive correlation observed (*r*=.448, *p*=.014).

8) **Foundation Paper 1 (Non-Calculator), Q28 – Translate situations or procedures into algebraic expressions formulae or equations. Hegartymaths clips associated: 550 – Perimeter (3); 554 – Rectangles.**
Assessment Objective: 2, Total marks: 4, EDEXCEL average marks: 1.42 (35.5%), UL Schools average: 1.6 (40.0%).
Medium positive correlation observed (*r*=.441, *p*=.017).

9) **Foundation Paper 2 (Calculator), Q8a – Simplify and manipulate algebraic expressions and fractions. Hegartymaths clips associated: 158 – Simplifying expressions involving multiplication.**
Assessment Objective: 1, Total marks: 1, EDEXCEL average marks: 0.83 (83.0%), UL Schools average: 0.90 (89.8%).
Medium positive correlation observed (*r*=.405, *p*=.030).

10) **Foundation Paper 2 (Calculator), Q8c – Simplify and manipulate algebraic expressions and fractions. Hegartymaths clips associated: 159 – Simplifying expressions involving division.**
Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 0.61 (30.5%), UL Schools average: 0.73 (36.4%).
Medium positive correlation observed (*r*=.402, *p*=.031).

11) **Foundation Paper 2 (Calculator), Q11 – Substitute values into formulae and expressions. Hegartymaths clips associated: 784 – Substitution (5).**
Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 1.47 (73.5%), UL Schools average: 1.59 (79.6%).
Medium positive correlation observed (*r*=.374, *p*=.046).

12) **Foundation Paper 2 (Calculator), Q14 – Ratio notation reduction to simplest form. Hegartymaths clips associated: 331 – Write the ratios in the form 1:n or n:1.**
Assessment Objective: 2, Total marks: 1, EDEXCEL average marks: 0.24 (24.0%), UL Schools average: 0.31 (31.3%).
Strong positive correlation observed (*r*=.585, *p*=.001).

13) **Foundation Paper 2 (Calculator), Q16ai – Theoretical probability; appropriate language; 0-1 probability scale. Hegartymaths clips associated: 149 – Conversions between FDP (summary); 46 – Compare decimal numbers; 350 – Express a probability in numbers.**
Assessment Objective: 2, Total marks: 1, EDEXCEL average marks: 0.82 (82.0%), UL Schools average: 0.82 (81.5%).
Medium positive correlation observed (*r*=.420, *p*=.023).

14) **Foundation Paper 2 (Calculator), Q16aii – Theoretical probability; appropriate language; 0-1 probability scale. Hegartymaths clips associated: 149 – Conversions between FDP (summary); 46 – Compare decimal numbers; 350 – Express a probability in numbers.**
Assessment Objective: 2, Total marks: 1, EDEXCEL average marks: 0.48 (48.0%), UL Schools average: 0.51 (51.0%).
Medium positive correlation observed (*r*=.442, *p*=.016).

15) **Foundation Paper 2 (Calculator), Q20a – Solve linear inequalities. Hegartymaths clips associated: 269 – Solve single linear inequalities 1 (positive x).**
Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 0.33 (16.5%), UL Schools average: 0.64 (32.2%).
Medium positive correlation observed (*r*=.433, *p*=.019).

16) **Foundation Paper 2 (Calculator), Q20b – Represent the solution set of inequality on a number line. Hegartymaths clips associated: 272 – Solve double linear inequalities; 265 – Representing inequalities on a number line.**
    Assessment Objective: 2, Total marks: 3, EDEXCEL average marks: 0.44 (14.7%), UL Schools average: 0.66 (22.0%).
    Medium positive correlation observed (r=.437, p=.018).

17) **Foundation Paper 2 (Calculator), Q21 – Graphs of linear functions. Hegartymaths clips associated: 208 – Straight line graphs 3.**
    Assessment Objective: 2, Total marks: 3, EDEXCEL average marks: 1.54 (51.3%), UL Schools average: 1.85 (61.5%).
    Strong positive correlation observed (r=.643, p<.001).

18) **Foundation Paper 2 (Calculator), Q24 – Pythagoras' theorem and trigonometry. Hegartymaths clips associated: 509 – Trigonometry (find side) (1).**
    Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 0.34 (17.0%), UL Schools average: 0.54 (27.2%).
    Strong positive correlation observed (r=.590, p=.001).

19) **Foundation Paper 2 (Calculator), Q27a – Standard form. Hegartymaths clips associated: 122 – Ordinary to standard form.**
    Assessment Objective: 1, Total marks: 1, EDEXCEL average marks: 0.39 (39.0%), UL Schools average: 0.52 (51.7%).
    Medium positive correlation observed (r=.484, p=.008).

20) **Foundation Paper 3 (Calculator), Q1 – Rounding; Inequality notation to specify error interval. Hegartymaths clips associated: 17 – Round numbers to the nearest 10, 100, 1000.**
    Assessment Objective: 1, Total marks: 1, EDEXCEL average marks: 0.96 (96.0%), UL Schools average: 0.96 (95.8%).
    Medium positive correlation observed (r=.373, p=.047).

21) **Foundation Paper 3 (Calculator), Q4 – Roots and powers. Hegartymaths clips associated: 102 – Index form 1 (intro).**
    Assessment Objective: 1, Total marks: 1, EDEXCEL average marks: 0.15 (15.0%), UL Schools average: 0.18 (17.9%).
    Medium positive correlation observed (r=.391, p=.036).

22) **Foundation Paper 3 (Calculator), Q5 – Percentages and problems involving percentage change. Hegartymaths clips associated: 82 – Convert percentages to fractions.**
    Assessment Objective: 1, Total marks: 1, EDEXCEL average marks: 0.86 (86.0%), UL Schools average: 0.89 (88.8%).
    Medium positive correlation observed (r=.403, p=.030).

23) **Foundation Paper 3 (Calculator), Q6 – Percentages and problems involving percentage change. Hegartymaths clips associated: 87 – Find percentages of amounts 4 (using calculator).**
    Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 1.68 (84.0%), UL Schools average: 1.74 (87.2%).
    Medium positive correlation observed (r=.406, p=.029).

24) **Foundation Paper 3 (Calculator), Q10 – One quantity as a fraction of another. Hegartymaths clips associated: 62 – Express one number as a fraction of another.**
Assessment Objective: 1, Total marks: 3, EDEXCEL average marks: 2.18 (72.7%), UL Schools average: 2.23 (74.4%).
Medium positive correlation observed (*r*=.475, *p*=.009).

25) **Foundation Paper 3 (Calculator), Q12 – Relate ratios to fractions and to linear functions. Hegartymaths clips associated: 330 – Write ratios as fractions/proportions.**
Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 1.31 (65.5%), UL Schools average: 1.45 (72.4%).
Medium positive correlation observed (*r*=.477, *p*=.009).

26) **Foundation Paper 3 (Calculator), Q18a – Measures of central tendency (median mean mode and modal class). Hegartymaths clips associated: 415 – Mode from frequency tables.**
Assessment Objective: 1, Total marks: 1, EDEXCEL average marks: 0.48 (48.0%), UL Schools average: 0.53 (53.1%).
Medium positive correlation observed (*r*=.387, *p*=.038).

27) **Foundation Paper 3 (Calculator), Q19 – Rearranging formulae to change the subject. Hegartymaths clips associated: 281 – Change the subject of the formula 2 (2-step).**
Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 0.46 (23.0%), UL Schools average: 0.84 (42.2%).
Medium positive correlation observed (*r*=.376, *p*=.044).

28) **Foundation Paper 3 (Calculator), Q20 – Properties of angles. Hegartymaths clips associated: 486 – Angles in a triangle (2); 560 – Interior angles in quadrilaterals.**
Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 0.84 (42.0%), UL Schools average: 0.84 (42.2%).
Medium positive correlation observed (*r*=.382, *p*=.041).

29) **Foundation Paper 3 (Calculator), Q25 – Growth and decay compound interest. Hegartymaths clips associated: 94 – Compound interest.**
Assessment Objective: 1, Total marks: 3, EDEXCEL average marks: 0.62 (20.7%), UL Schools average: 0.72 (24.1%).
Strong positive correlation observed (*r*=.631, *p*<.001).

30) **Foundation Paper 3 (Calculator), Q30 – Solve two simultaneous equations. Hegartymaths clips associated: 94 – Compound interest.**
Assessment Objective: 1, Total marks: 3, EDEXCEL average marks: 0.52 (17.3%), UL Schools average: 1.02 (34.1%).
Medium positive correlation observed (*r*=.495, *p*=.006).

31) **Higher Paper 1 (Non-Calculator), Q18a – Calculate exactly with surds. Hegartymaths clips associated: 115 – Simplifying surds.**
Assessment Objective: 2, Total marks: 2, EDEXCEL average marks: 1.11 (55.5%), UL Schools average: 1.23 (61.7%).
Medium positive correlation observed (*r*=.498, *p*=.006).

32) **Higher Paper 1 (Non-Calculator), Q21b – Inverse and composite functions; formal function notation. Hegartymaths clips associated: 294 – Composite functions 2.**
Assessment Objective: 2, Total marks: 5, EDEXCEL average marks: 1.95 (39.0%), UL Schools average: 2.24 (44.7%).
Strong positive correlation observed (*r*=.507, *p*=.005).

33) **Higher Paper 2 (Calculator), Q1b – Represent the solution set of inequality on a number line. Hegartymaths clips associated: 272 – Solve double linear inequalities; 265 – Representing inequalities on a number line.**
Assessment Objective: 2, Total marks: 3, EDEXCEL average marks: 1.36 (45.3%), UL Schools average: 1.45 (48.5%).
Medium positive correlation observed (*r*=.405, *p*=.029).

34) **Higher Paper 2 (Calculator), Q5 – Pythagoras' theorem and trigonometry. Hegartymaths clips associated: 509 – Trigonometry (find side) (1).**
Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 1.65 (82.5%), UL Schools average: 1.69 (84.7%).
Medium positive correlation observed (*r*=.378, *p*=.043).

35) **Higher Paper 2 (Calculator), Q10a – Enumerate sets and combinations of sets systematically; two-way tables Venn diagrams and tree diagrams. Hegartymaths clips associated: 361 – .**
Assessment Objective: 2, Total marks: 2, EDEXCEL average marks: 1.94 (97.0%), UL Schools average: 1.95 (97.6%).
Medium positive correlation observed (*r*=.414, *p*=.025).

36) **Higher Paper 2 (Calculator), Q15 – Rearrange formulae to change the subject. Hegartymaths clips associated: 286 – Change the subject of a formula 7 (x on both sides/denominator).**
Assessment Objective: 1, Total marks: 3, EDEXCEL average marks: 1.35 (45.0%), UL Schools average: 1.82 (60.6%).
Medium positive correlation observed (*r*=.433, *p*=.019).

37) **Higher Paper 2 (Calculator), Q16 – Graphs and equations of lines. Hegartymaths clips associated: 216 – Straight line graphs (perpendicular) 2.**
Assessment Objective: 3, Total marks: 3, EDEXCEL average marks: 0.93 (31.0%), UL Schools average: 1.00 (33.5%).
Medium positive correlation observed (*r*=.482, *p*=.008).

38) **Higher Paper 3 (Calculator), Q15 – Translations and reflections of a function. Hegartymaths clips associated: 313 – Graph transformations 7 (combined).**
Assessment Objective: 1, Total marks: 2, EDEXCEL average marks: 0.56 (28.0%), UL Schools average: 0.52 (25.9%).
Strong positive correlation observed (*r*=.613, *p*<.001).

39) **Higher Paper 3 (Calculator), Q16 – The nth term of a sequence. Hegartymaths clips associated: 248 – Find the nth term of a quadratic sequence.**
Assessment Objective: 1, Total marks: 3, EDEXCEL average marks: 2.02 (67.3%), UL Schools average: 2.14 (71.4%).
Strong positive correlation observed (*r*=.559, *p*=.002).

40) Higher Paper 3 (Calculator), Q23 – Sine and cosine rule. Hegartymaths clips associated: 531 – Bearings (sine and cosine rule).

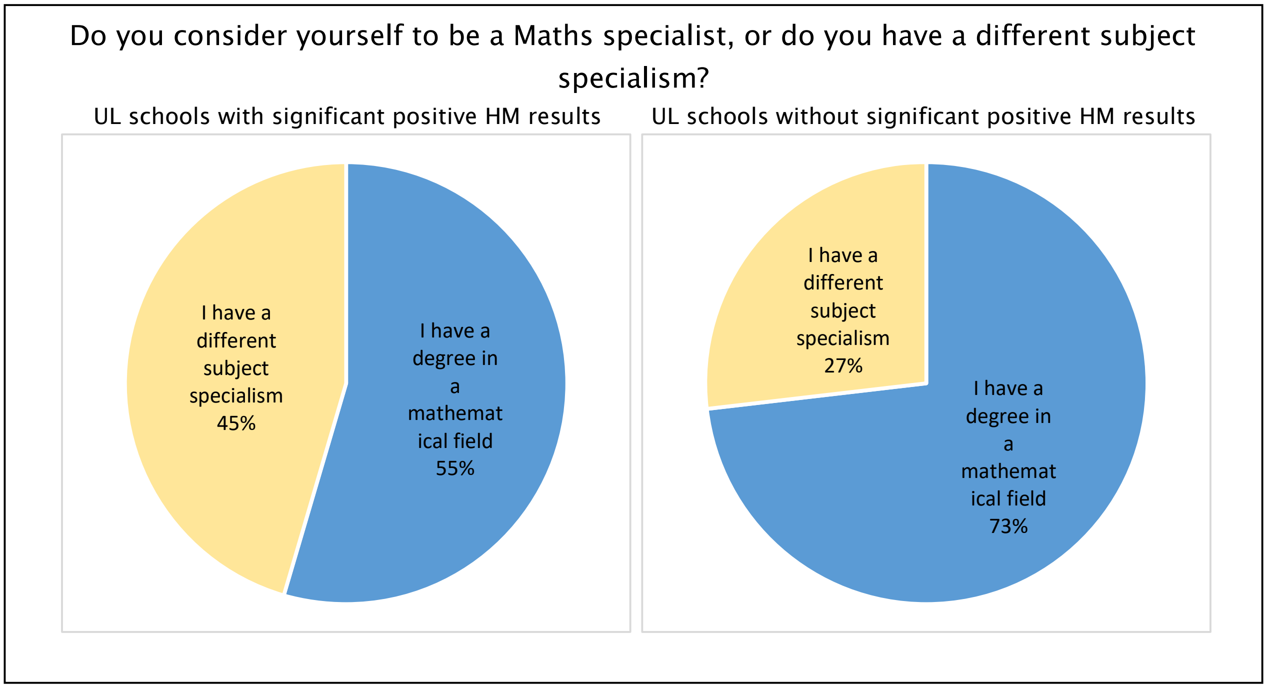
Assessment Objective: 3, Total marks: 5, EDEXCEL average marks: 0.86 (17.2%), UL Schools average: 0.89 (17.8%).

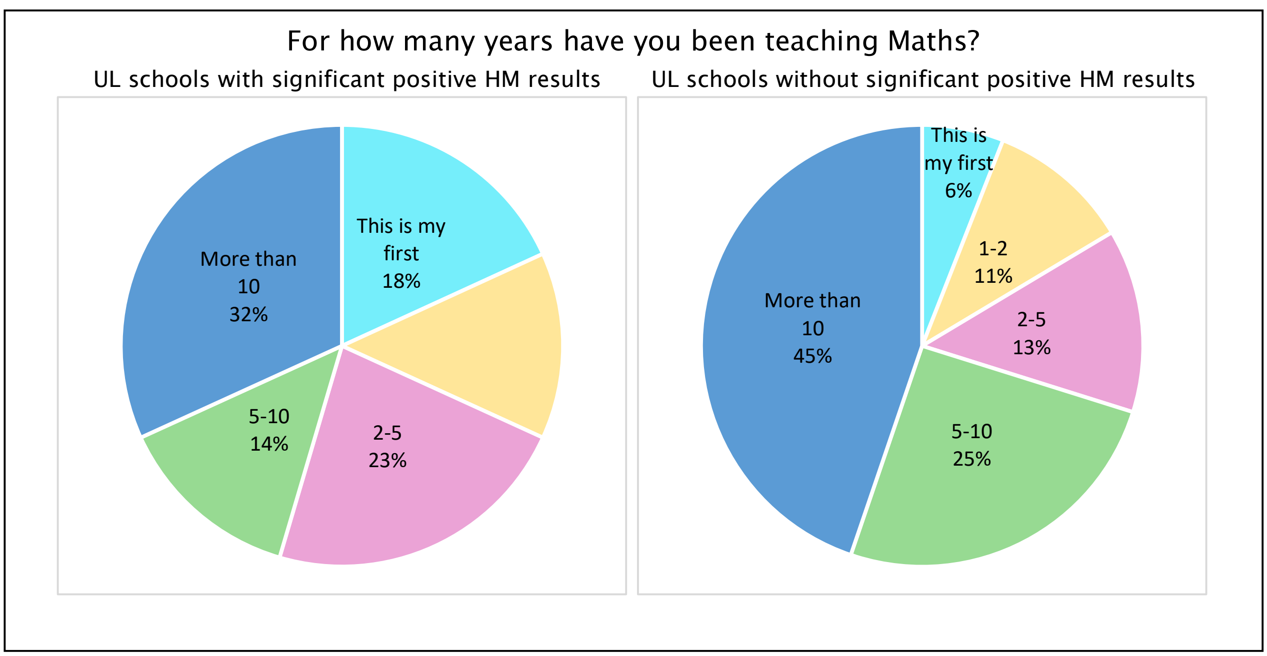
Strong positive correlation observed (r=.644, p<.001).

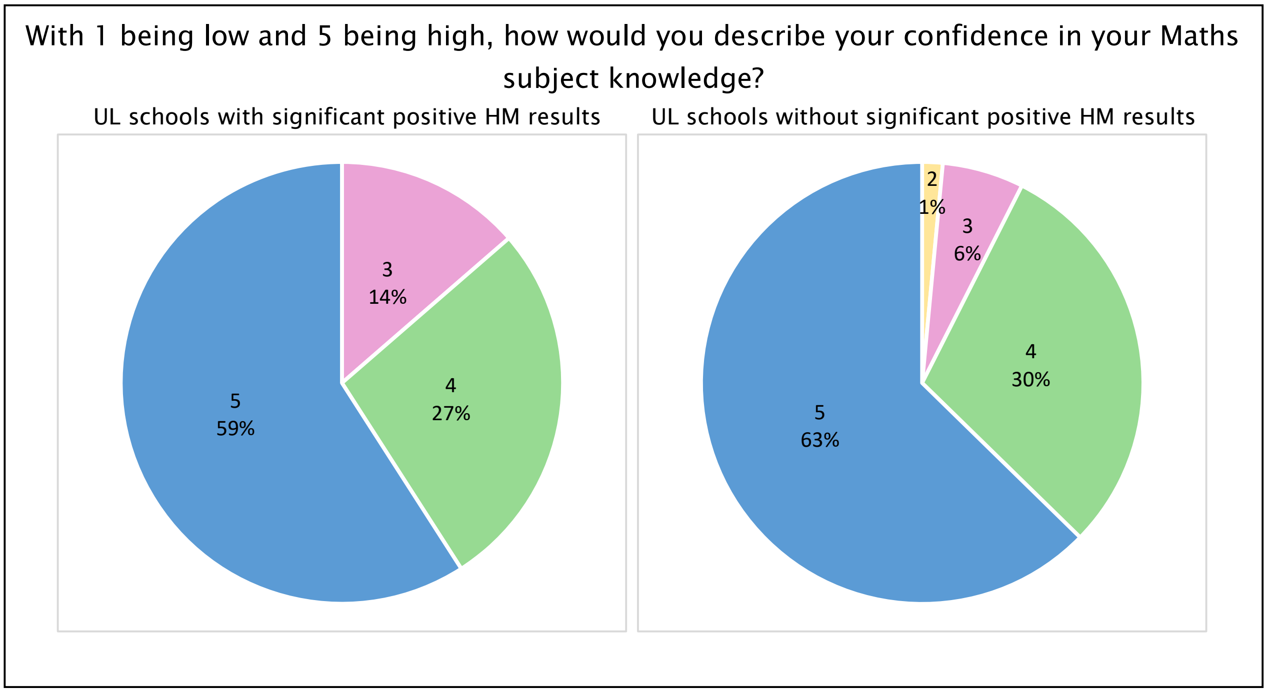
Appendix Q: Teacher survey grouped analysis

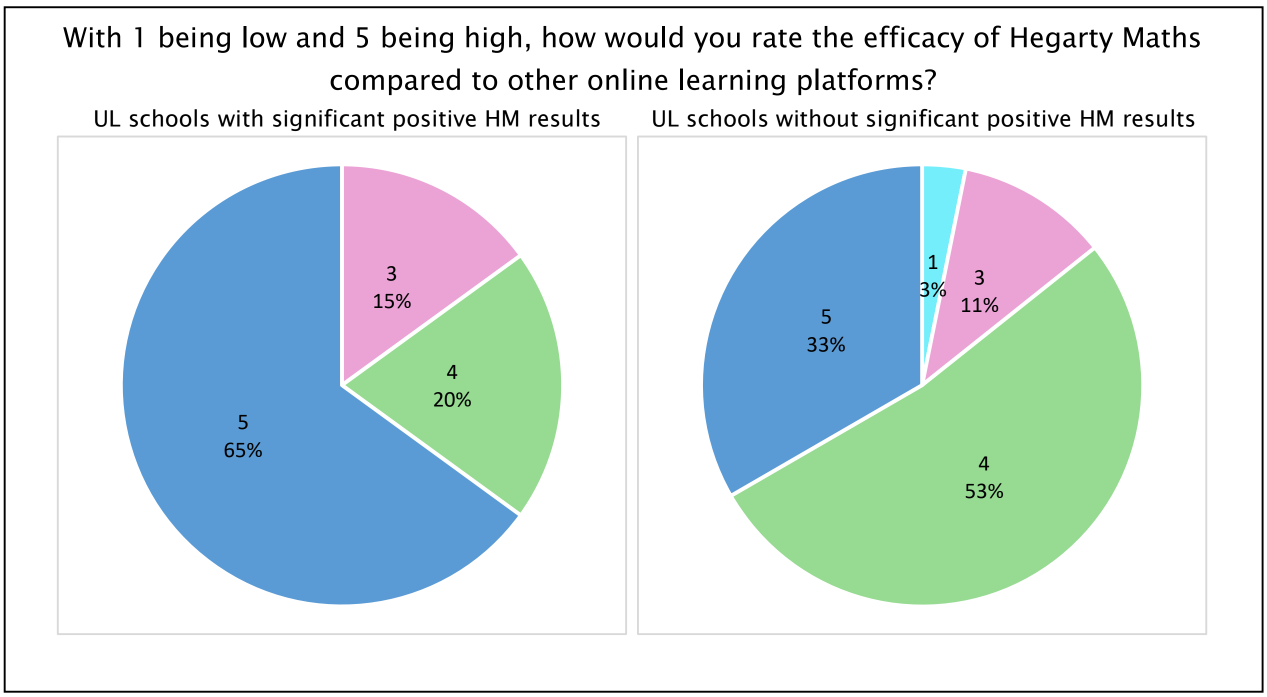
Results of the teacher survey showing the differences between teachers of schools that had positive and significant Hegartymaths correlations (time spent on Hegartymaths with GCSE performance), and teachers of schools that did not show statistically significant results.

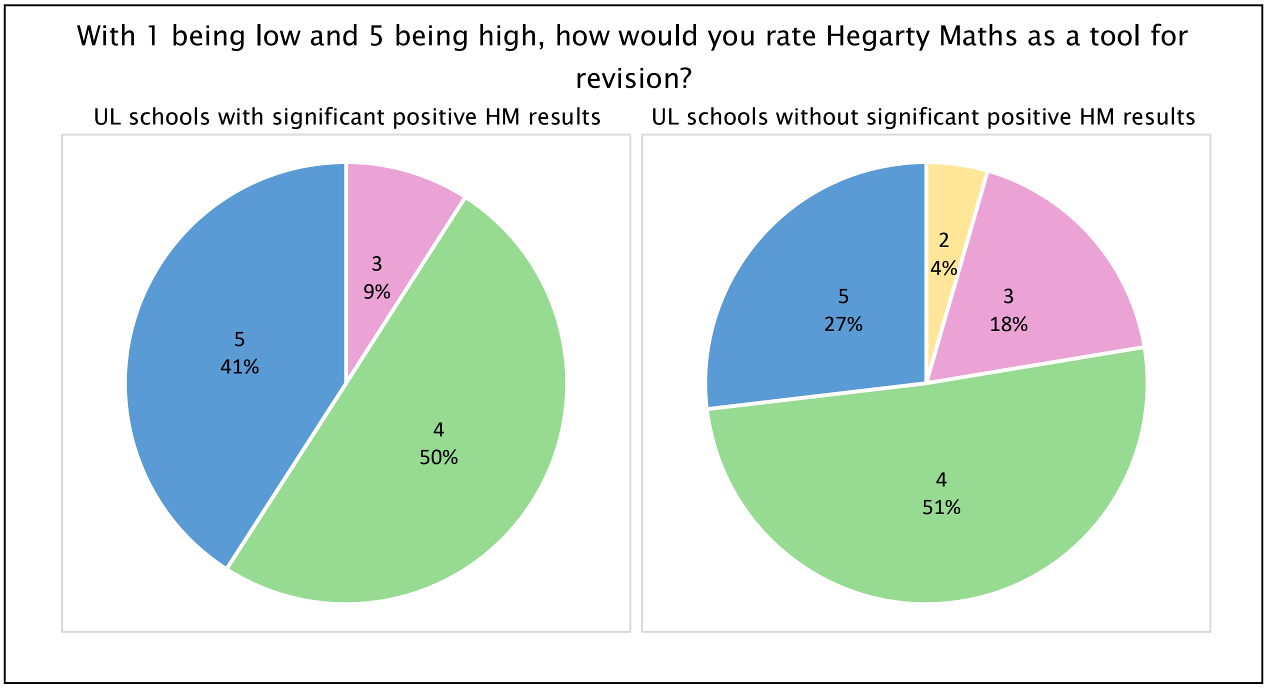
Overall results

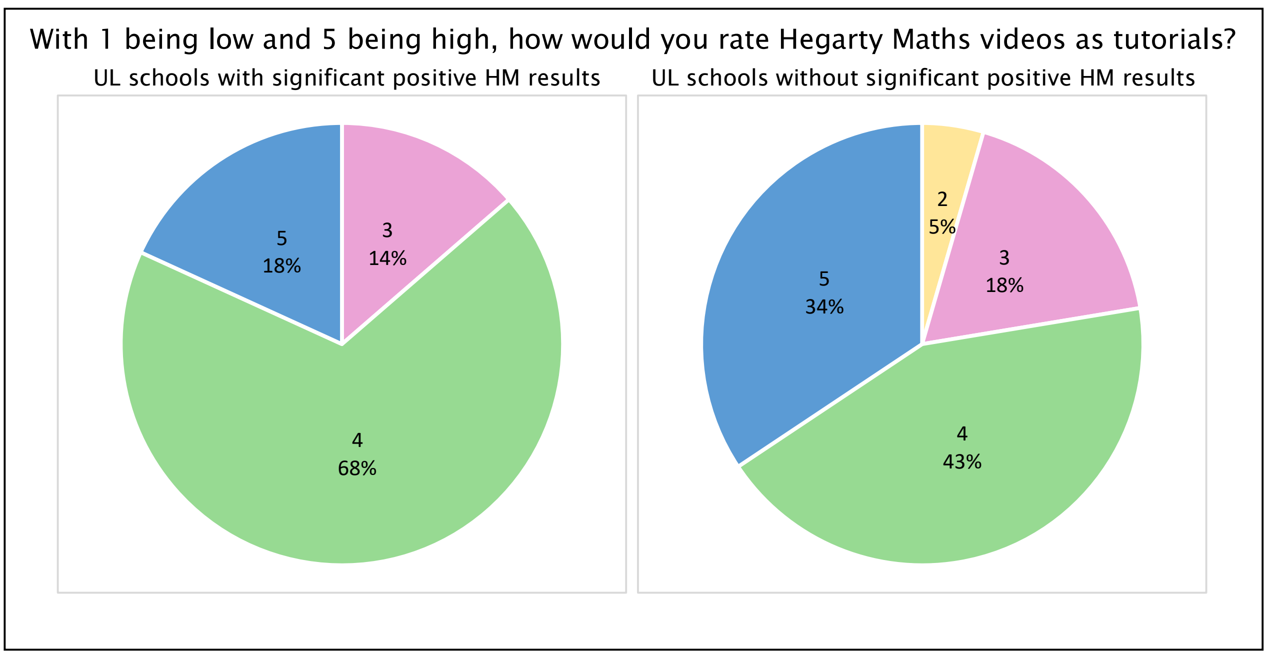


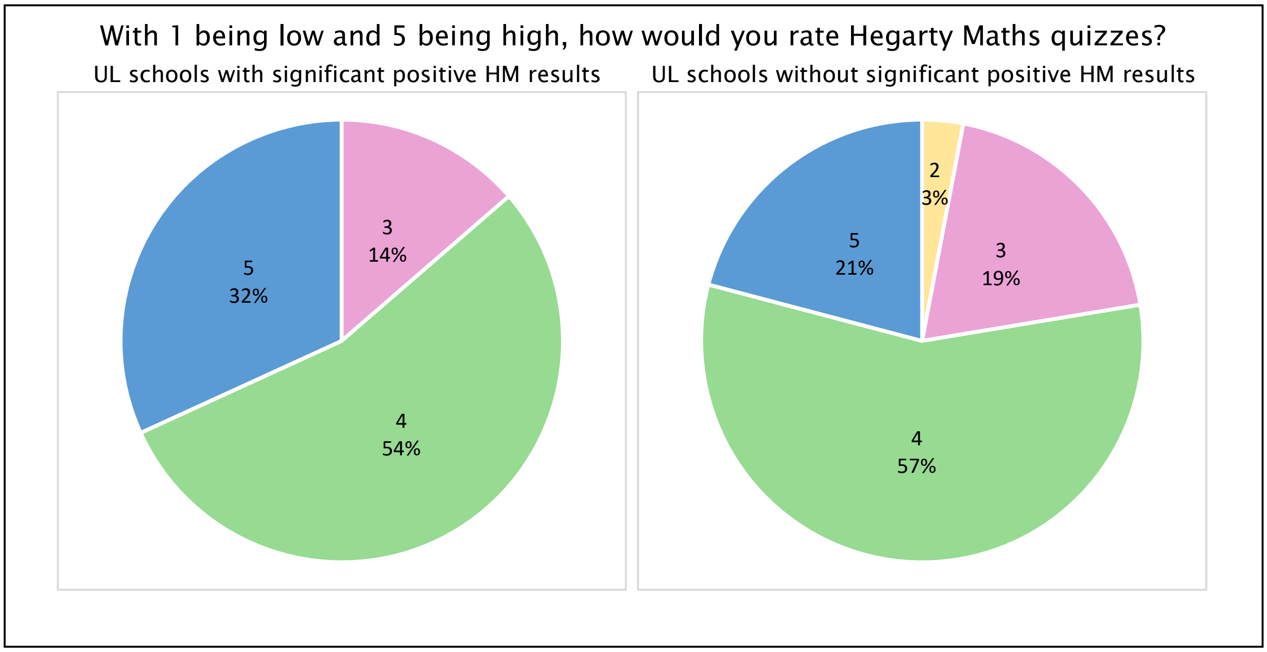


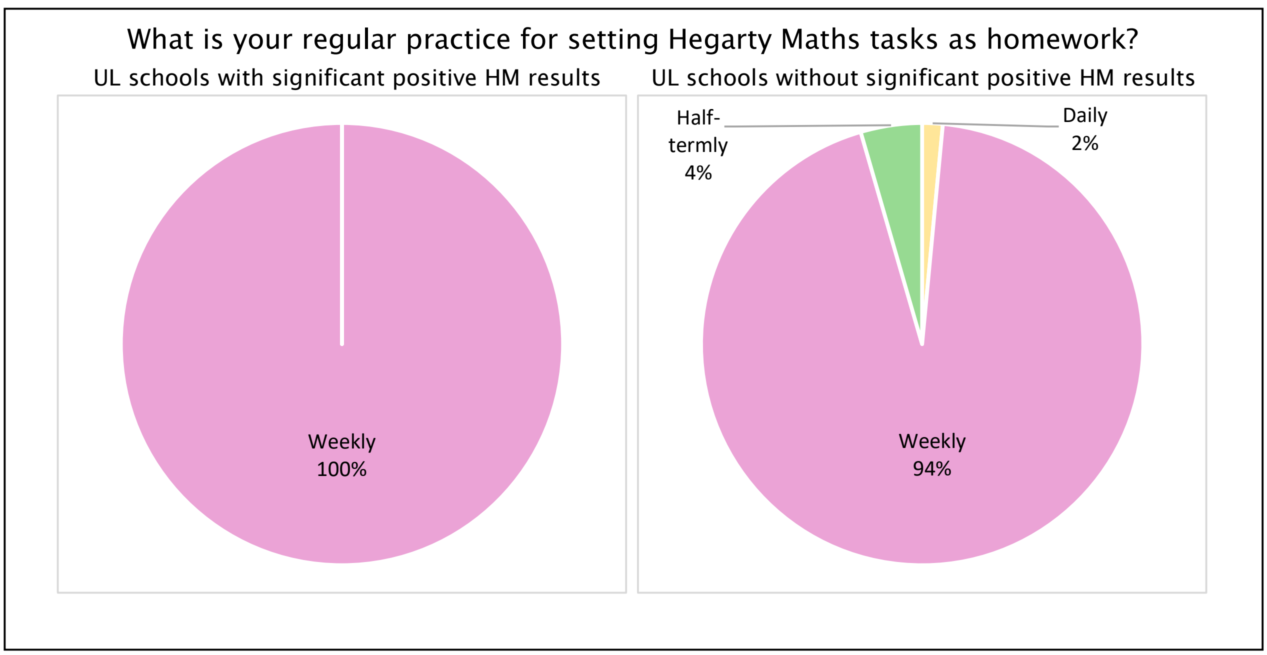

With 1 being low and 5 being high, how would you describe your confidence in your Maths subject knowledge?
UL schools with significant positive HM results
3 14%
4 27%
5 59%
UL schools without significant positive HM results
2 1%
3 6%
4 30%
5 63%

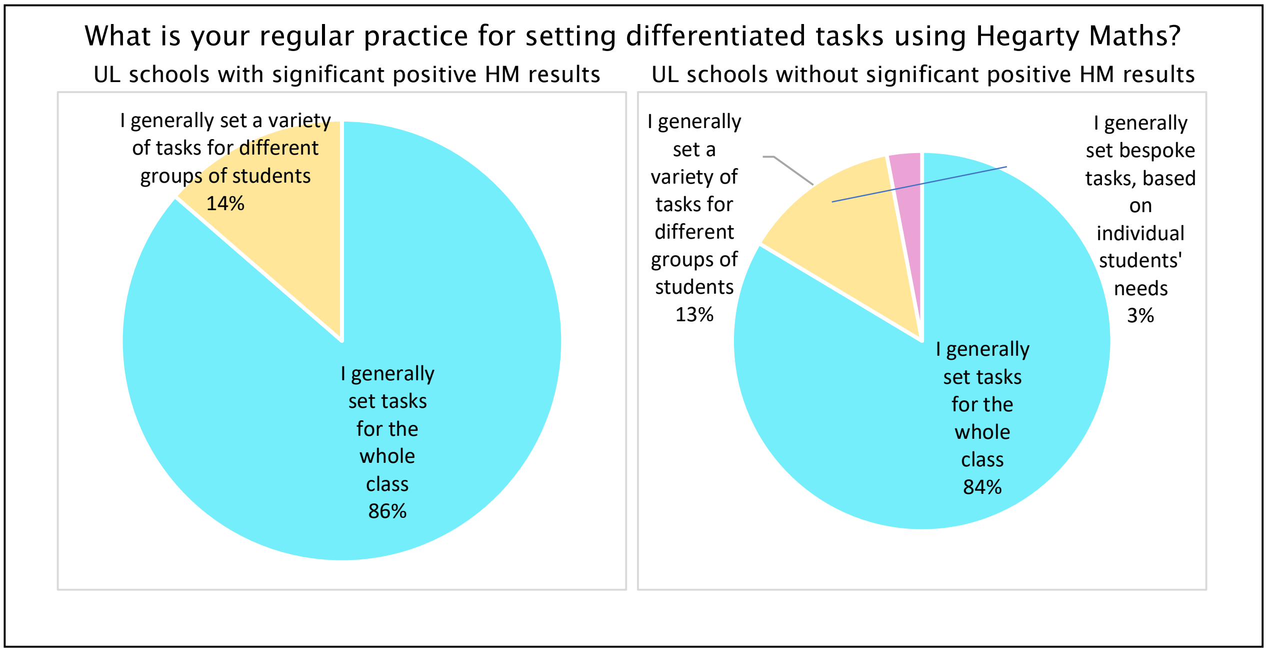

With 1 being low and 5 being high, how would you rate the efficacy of Hegarty Maths compared to other online learning platforms?
UL schools with significant positive HM results
3 15%
4 20%
5 65%
UL schools without significant positive HM results
1 3%
3 11%
4 53%
5 33%

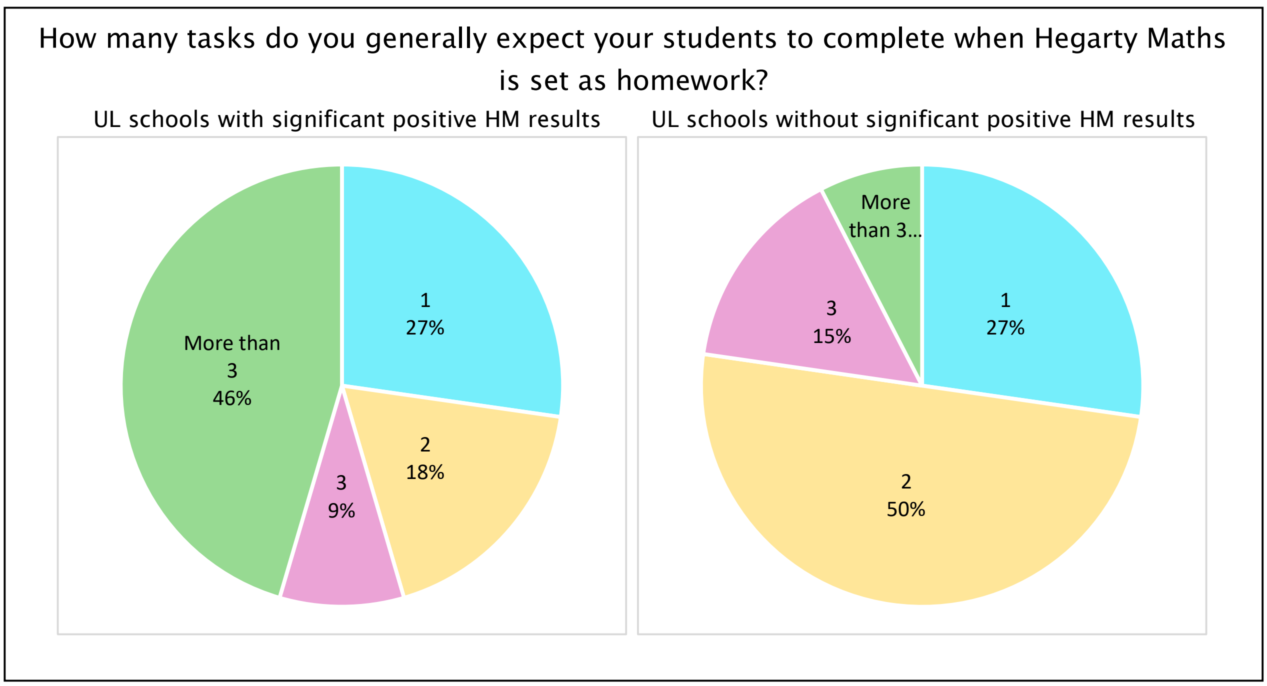

With 1 being low and 5 being high, how would you rate Hegarty Maths as a tool for revision?
UL schools with significant positive HM results
3
9%
5
41%
4
50%
UL schools without significant positive HM results
2
4%
5
27%
3
18%
4
51%

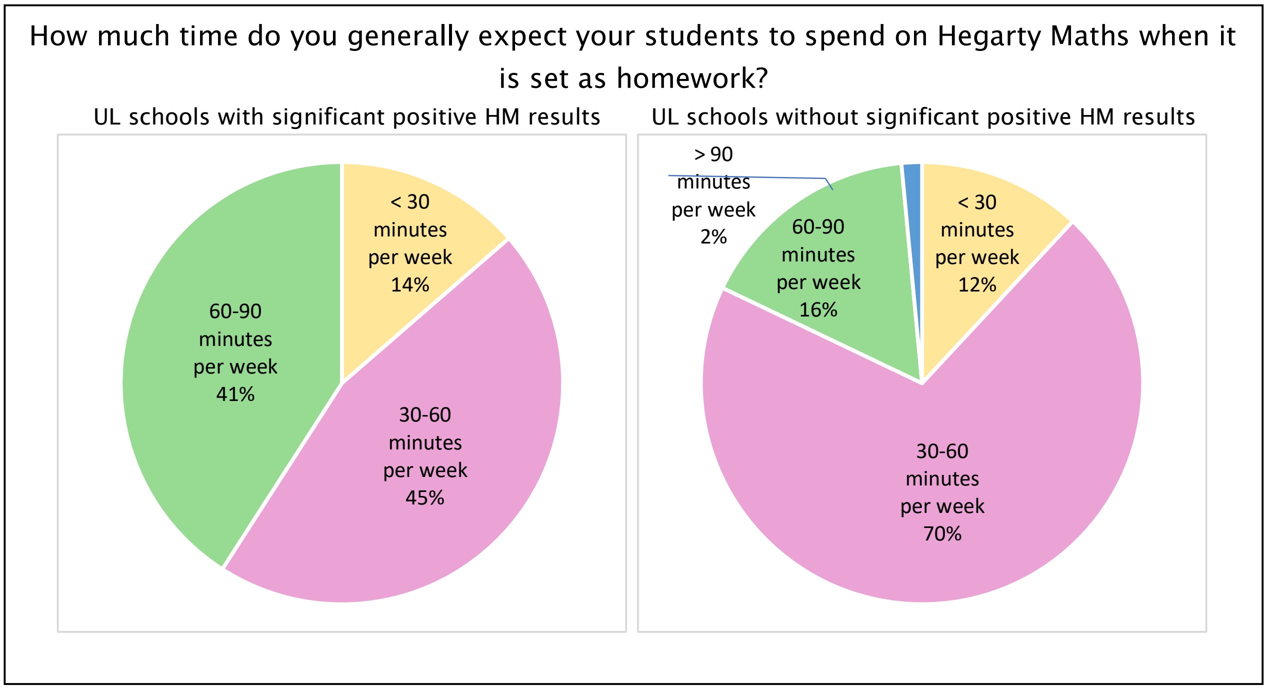

With 1 being low and 5 being high, how would you rate Hegarty Maths videos as tutorials?
UL schools with significant positive HM results
5
18%
3
14%
4
68%
UL schools without significant positive HM results
2
5%
3
18%
5
34%
4
43%

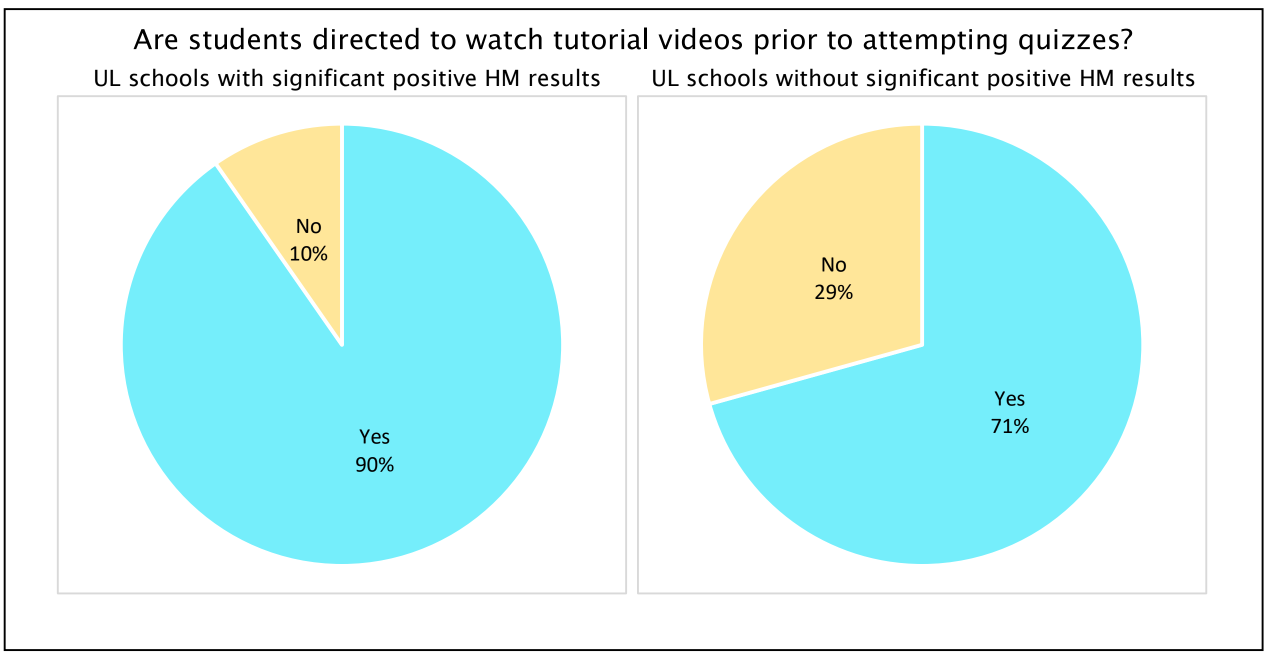

With 1 being low and 5 being high, how would you rate Hegarty Maths quizzes?
UL schools with significant positive HM results
3
14%
5
32%
4
54%
UL schools without significant positive HM results
2
3%
5
21%
3
19%
4
57%

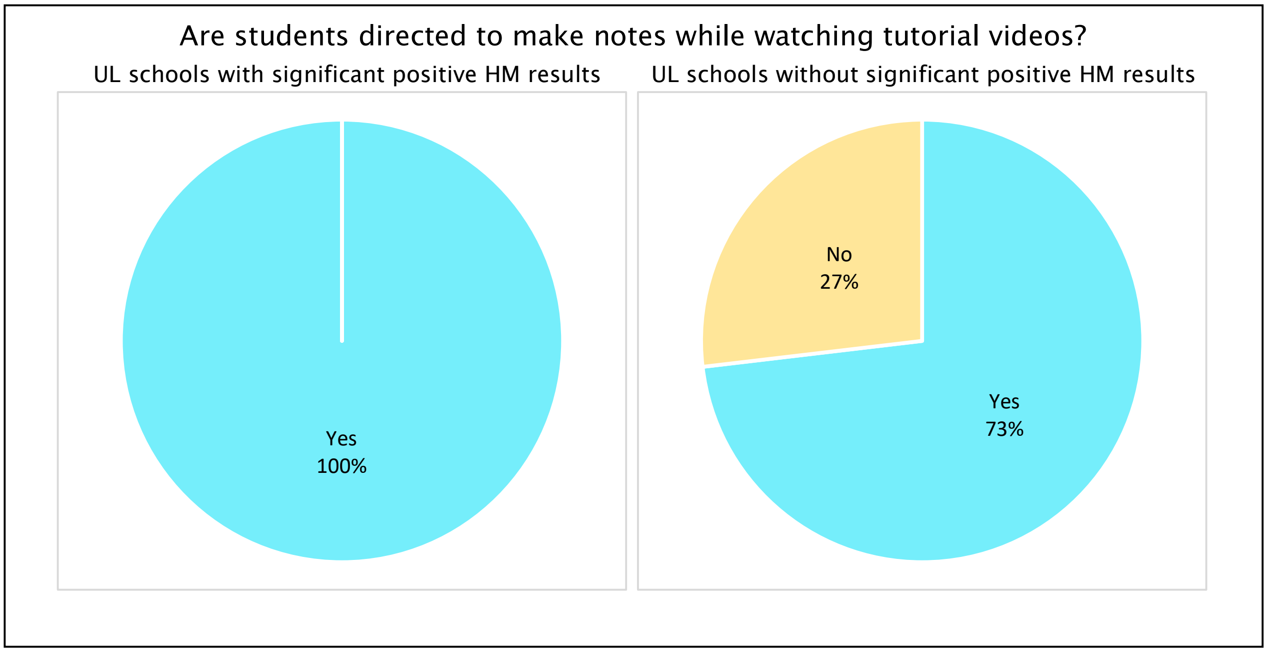

What is your regular practice for setting Hegarty Maths tasks as homework?
UL schools with significant positive HM results
Weekly
100%
UL schools without significant positive HM results
Half-termly
4%
Daily
2%
Weekly
94%

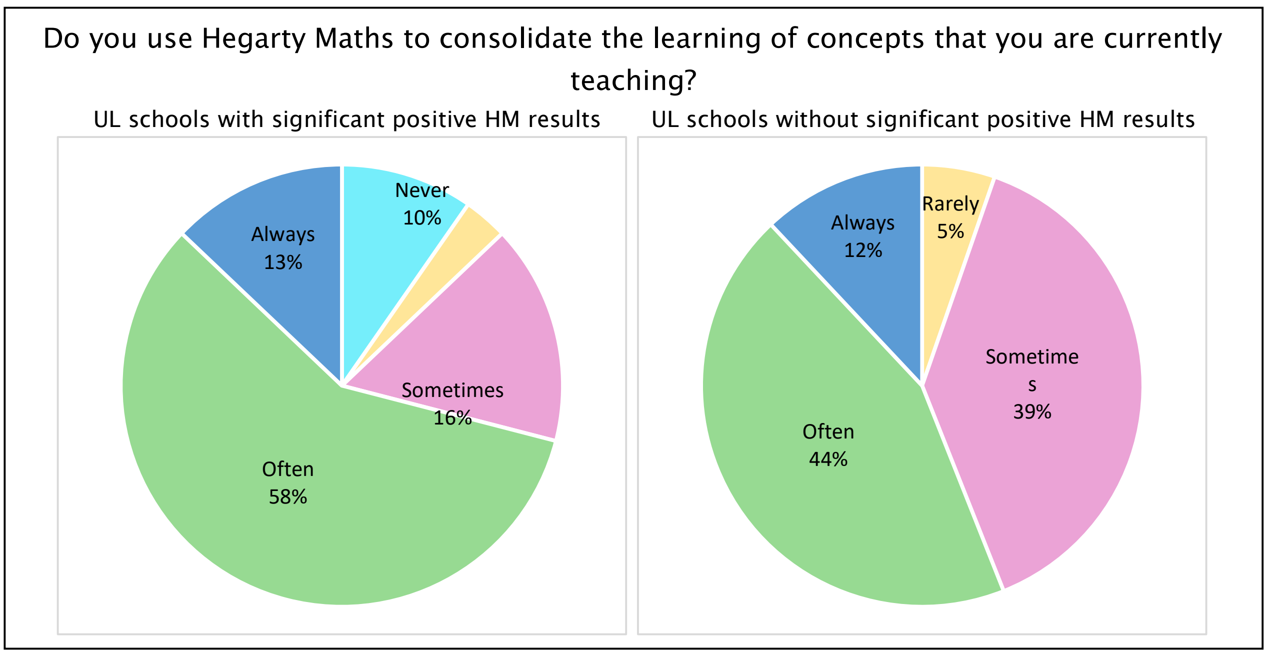

What is your regular practice for setting differentiated tasks using Hegarty Maths?
UL schools with significant positive HM results
I generally set a variety of tasks for different groups of students 14%
I generally set tasks for the whole class 86%
UL schools without significant positive HM results
I generally set a variety of tasks for different groups of students 13%
I generally set bespoke tasks, based on individual students' needs 3%
I generally set tasks for the whole class 84%

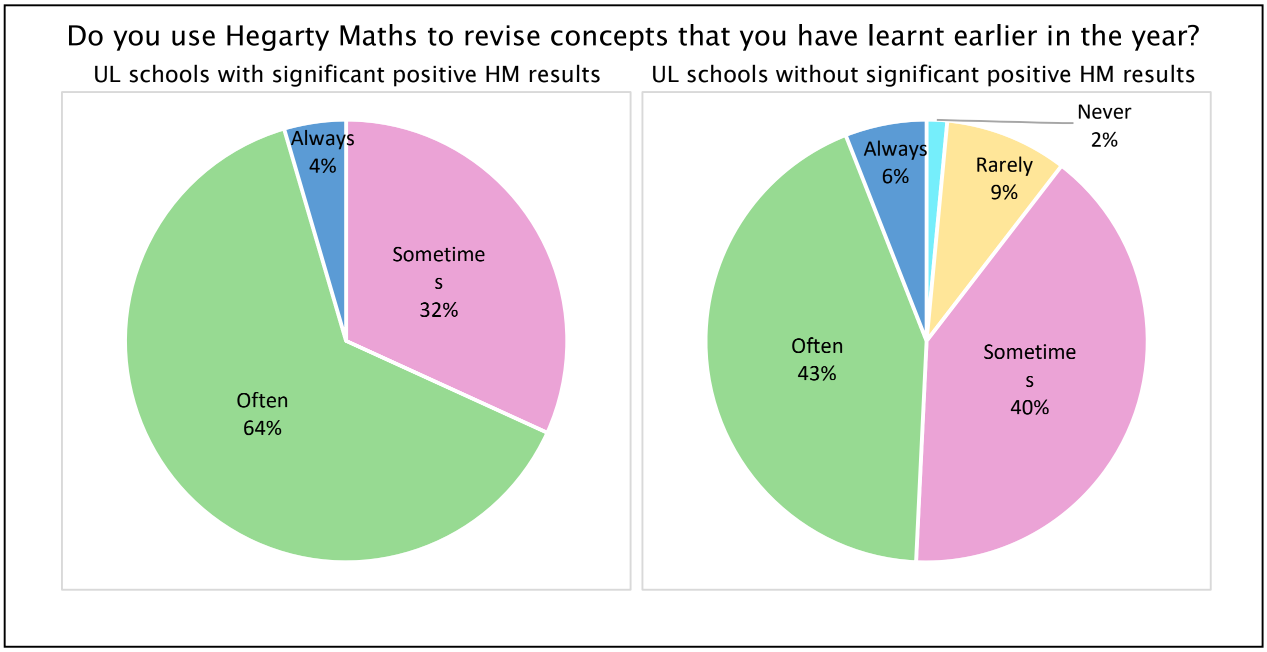

How many tasks do you generally expect your students to complete when Hegarty Maths is set as homework?
UL schools with significant positive HM results
1 27%
2 18%
3 9%
More than 3 46%
UL schools without significant positive HM results
More than 3...
1 27%
3 15%
2 50%

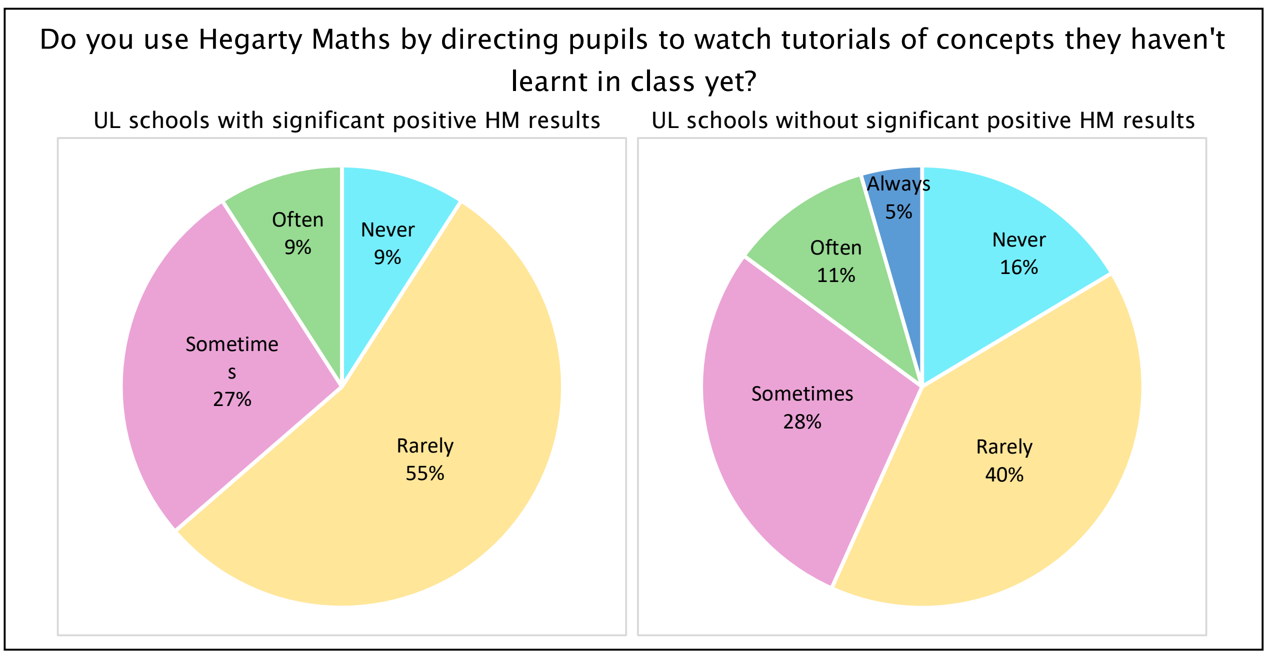

How much time do you generally expect your students to spend on Hegarty Maths when it is set as homework?
UL schools with significant positive HM results
< 30 minutes per week 14%
30-60 minutes per week 45%
60-90 minutes per week 41%
UL schools without significant positive HM results
> 90 minutes per week 2%
60-90 minutes per week 16%
< 30 minutes per week 12%
30-60 minutes per week 70%

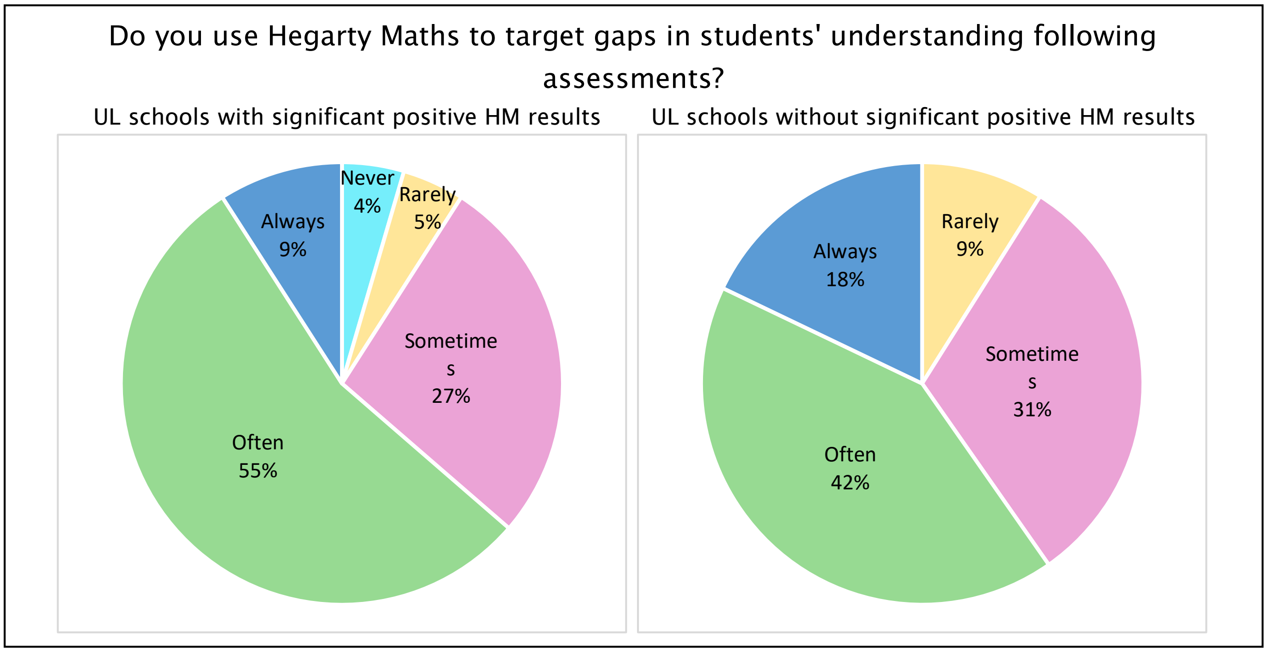

Are students directed to watch tutorial videos prior to attempting quizzes?
UL schools with significant positive HM results
No 10%
Yes 90%
UL schools without significant positive HM results
No 29%
Yes 71%


Are students directed to make notes while watching tutorial videos?
UL schools with significant positive HM results
UL schools without significant positive HM results
Yes
100%
No
27%
Yes
73%


Do you use Hegarty Maths to consolidate the learning of concepts that you are currently teaching?
UL schools with significant positive HM results
UL schools without significant positive HM results
Never
10%
Always
13%
Sometimes
16%
Often
58%
Always
12%
Rarely
5%
Sometime
s
39%
Often
44%


Do you use Hegarty Maths to revise concepts that you have learnt earlier in the year?
UL schools with significant positive HM results
Always
4%
Sometime
s
32%
Often
64%
UL schools without significant positive HM results
Never
2%
Always
6%
Rarely
9%
Often
43%
Sometime
s
40%


Do you use Hegarty Maths by directing pupils to watch tutorials of concepts they haven't learnt in class yet?
UL schools with significant positive HM results
Often
9%
Never
9%
Sometime
s
27%
Rarely
55%
UL schools without significant positive HM results
Always
5%
Never
16%
Often
11%
Sometimes
28%
Rarely
40%


Do you use Hegarty Maths to target gaps in students' understanding following assessments?
UL schools with significant positive HM results
Never 4%
Rarely 5%
Always 9%
Sometimes 27%
Often 55%
UL schools without significant positive HM results
Always 18%
Rarely 9%
Sometimes 31%
Often 42%

Appendix R: Chi-square test calculation for the teacher survey

Chi-square analyses of the results of the teacher survey showing the differences between teachers of schools that had positive and significant Hegartymaths correlations (time spent on Hegartymaths with GCSE performance), and teachers of schools that did not show statistically significant results.

Do you consider yourself to be a Maths specialist, or do you have a different subject specialism?

		I have a degree in a mathematical field	I have a different subject specialism	
Actual	Positive significant results using HI	19	12	31
	Non significant results using HM	55	20	75
		74	32	106
Expecte	Positive significant results using HI	21.64150943	9.358490566	
	Non significant results using HM	52.35849057	22.64150943	
	Chi - squared	1.509444929		
	p	21.92238%		
	phi	0.119331666		

For how many years have you been teaching Maths?

		This is my first	1-2	2-5	5-10	More than 10	
Actual	Positive significant results using HI	5	3	8	6	9	31
	Non significant results using HM	5	8	11	18	33	75
		10	11	19	24	42	106
Expecte	Positive significant results using HI	2.924528302	3.216981132	5.55660377	7.01886792	12.2830189	
	Non significant results using HM	7.075471698	7.783018868	13.4433962	16.9811321	29.7169811	
	Chi - squared	5.070149861					
	p	28.01751%					
	phi	0.218704372					

This is my first	opp		1-2	opp		2-5	opp		5-10	opp		More than 1	opp	
5	26	31	3	28	31	8	23	31	6	25	31	9	22	31
5	70	75	8	67	75	11	64	75	18	57	75	33	42	75
10	96	106	11	95	106	19	87	106	24	82	106	42	64	106
2.924528302	28.1		3.2169811	27.8		5.5566038	25.4		7.0188679	24		12.283019	18.7	
7.075471698	67.9		7.7830189	67.2		13.443396	61.6		16.981132	58		29.716981	45.3	
2.298566308			0.0230793			1.8501613			0.2702124			2.0540553		
12.94935%			87.92511%			17.37646%			60.31893%			15.18014%		
0.147256877			0.0147556			0.1321149			0.0504893			0.1392045		

With 1 being low and 5 being high, how would you describe your confidence in your Maths subject knowledge?

		1	2	3	4	5	
Actual	Positive significant results using HI	0	0	4	11	16	31
	Non significant results using HM	0	1	4	23	47	75
		0	1	8	34	63	106
Expecte	Positive significant results using HI	0	0.29245283	2.33962264	9.94339623	18.4245283	
	Non significant results using HM	0	0.70754717	5.66037736	24.0566038	44.5754717	
	Chi - squared	2.68831742					
	p	44.22163%					
	phi	0.159252897					

1	opp		2	opp		3	opp		4	opp		5	opp	
0	31	31	0	31	31	4	27	31	11	20	31	16	15	31
0	75	75	1	74	75	4	71	75	23	52	75	47	28	75
0	106	106	1	105	106	8	98	106	34	72	106	63	43	106
0	31		0.2924528	30.7		2.3396226	28.7		9.9433962	21.1		18.424528	12.6	
0	75		0.7075472	74.3		5.6603774	69.3		24.056604	50.9		44.575472	30.4	
#VALUE!			0.4172698			1.8013254			0.2336187			1.1115785		
#DIV/0!			51.83025%			17.95523%			62.88535%			29.17391%		
#VALUE!			0.0627416			0.1303596			0.0469462			0.1024041		

With 1 being low and 5 being high, how would you rate the efficacy of Hegarty Maths compared to other online learning platforms?

		1	3	4	5		
Actual	Positive significant results using HI	0	4	10	15	29	
	Non significant results using HM	2	11	37	21	71	
		2	15	47	36	100	
Expecte	Positive significant results using HI	0.58	4.35	13.63	10.44		
	Non significant results using HM	1.42	10.65	33.37	25.56		
	Chi - squared	5.023439734					
	p	17.00888%					
	phi	0.224130313					

1	opp		3	opp		4	opp		5	opp		0	opp	
0	0	0	4	-4	0	10	-10	0	15	-15	0	29	-29	0
2	-2	0	11	-11	0	37	-37	0	21	-21	0	71	-71	0
2	-2	0	15	-15	0	47	-47	0	36	-36	0	100	-100	0
#DIV/0!	####		#DIV/0!	####		#DIV/0!	####		#DIV/0!	####		#DIV/0!	####	
#DIV/0!	####		#DIV/0!	####		#DIV/0!	####		#DIV/0!	####		#DIV/0!	####	
#VALUE!			#VALUE!			#VALUE!			#VALUE!			#VALUE!		
#DIV/0!			#DIV/0!			#DIV/0!			#DIV/0!			#DIV/0!		
#VALUE!			#VALUE!			#VALUE!			#VALUE!			#VALUE!		

With 1 being low and 5 being high, how would you rate Hegarty Maths as a tool for revision?

		1	2	3	4	5	
Actual	Positive significant results using HI	0	0	5	14	12	31
	Non significant results using HM	0	3	12	41	19	75
		0	3	17	55	31	106
Expectec	Positive significant results using HI	0	0.877358491	4.97169811	16.0849057	9.06603774	
	Non significant results using HM	0	2.122641509	12.0283019	38.9150943	21.9339623	
	Chi - squared	2.964120366					
	p	39.71903%					
	phi	0.167222605					

1	opp	
0	31	31
0	75	75
0	106	106
0	31	
0	75	
#VALUE!		
#DIV/0!		
#VALUE!		

2	opp	
0	31	31
3	72	75
3	103	106
0.8773585	30.1	
2.1226415	72.9	
1.2761165		
25.86224%		
0.1097216		

3	opp	
5	26	31
12	63	75
17	89	106
4.9716981	26	
12.028302	63	
0.0002712		
98.68610%		
0.0015995		

4	opp	
14	17	31
41	34	75
55	51	106
16.084906	14.9	
38.915094	36.1	
0.7938429		
37.29406%		
0.0865395		

5	opp	
12	19	31
19	56	75
31	75	106
9.0660377	21.9	
21.933962	53.1	
1.8966218		
16.84569%		
0.1337634		

With 1 being low and 5 being high, how would you rate Hegarty Maths videos as tutorials?

		1	2	3	4	5	
Actual	Positive significant results using HI	0	1	4	20	6	31
	Non significant results using HM	0	5	14	32	24	75
		0	6	18	52	30	106
Expectec	Positive significant results using HI	0	1.754716981	5.26415094	15.2075472	8.77358491	
	Non significant results using HM	0	4.245283019	12.7358491	36.7924528	21.2264151	
	Chi - squared	4.261587722					
	p	23.45677%					
	phi	0.200508498					

1	opp	
0	31	31
0	75	75
0	106	106
0	31	
0	75	
#VALUE!		
#DIV/0!		
#VALUE!		

2	opp	
1	30	31
5	70	75
6	100	106
1.754717	29.2	
4.245283	70.8	
0.4863082		
48.55788%		
0.0677334		

3	opp	
4	27	31
14	61	75
18	88	106
5.2641509	25.7	
12.735849	62.3	
0.5168176		
47.22024%		
0.0698258		

4	opp	
20	11	31
32	43	75
52	54	106
15.207547	15.8	
36.792453	38.2	
4.1899923		
4.06633%		
0.1988171		

5	opp	
6	25	31
24	51	75
30	76	106
8.7735849	22.2	
21.226415	53.8	
1.7283939		
18.86161%		
0.1276934		

With 1 being low and 5 being high, how would you rate Hegarty Maths quizzes?

		1	2	3	4	5	
Actual	Positive significant results using HI	0	0	7	17	7	31
	Non significant results using HM	0	2	18	40	15	75
		0	2	25	57	22	106
Expectec	Positive significant results using HI	0	0.58490566	7.31132075	16.6698113	6.43396226	
	Non significant results using HM	0	1.41509434	17.6886792	40.3301887	15.5660377	
	Chi - squared	0.925026921					
	p	81.93844%					
	phi	0.093416642					

1	opp	
0	31	31
0	75	75
0	106	106
0	31	
0	75	
#VALUE!		
#DIV/0!		
#VALUE!		

2	opp	
0	31	31
2	73	75
2	104	106
0.5849057	30.4	
1.4150943	73.6	
0.8425641		
35.86645%		
0.0891556		

3	opp	
7	24	31
18	57	75
25	81	106
7.3113208	23.7	
17.688679	57.3	
0.024518		
87.55740%		
0.0152086		

4	opp	
17	14	31
40	35	75
57	49	106
16.669811	14.3	
40.330189	34.7	
0.0199962		
88.75476%		
0.0137348		

5	opp	
7	24	31
15	60	75
22	84	106
6.4339623	24.6	
15.566038	59.4	
0.0888144		
76.56898%		
0.028946		

What is your regular practice for setting Hegarty Maths tasks as homework?

		Rarely/Never	Daily	Weekly	Half-termly	
Actual	Positive significant results using HI	0	0	31	0	31
	Non significant results using HM	1	1	68	5	75
		1	1	99	5	106
Expectec	Positive significant results using HI	0.29245283	0.29245283	28.9528302	1.46226415	
	Non significant results using HM	0.70754717	0.70754717	70.0471698	3.53773585	
	Chi - squared	2.684579125				
	p	26.12468%				
	phi	0.159142132				

Rarely/Never	opp	
0	31	31
1	74	75
1	105	106
0.29245283	30.7	
0.70754717	74.3	
0.417269841		
51.83025%		
0.062741597		

Daily	opp	
0	31	31
1	74	75
1	105	106
0.2924528	30.7	
0.7075472	74.3	
0.4172698		
51.83025%		
0.0627416		

Weekly	opp	
31	0	31
68	7	75
99	7	106
28.95283	2.05	
70.04717	4.95	
3.0979125		
7.83928%		
0.1709549		

Half-termly	opp	
0	31	31
5	70	75
5	101	106
1.4622642	29.5	
3.5377358	71.5	
2.1689769		
14.08199%		
0.1430456		

What is your regular practice for setting differentiated tasks using Hegarty Maths?

		I generally set tasks for the \	I generally set a \	I generally set bespoke tasks, based on individual stu		
Actual	Positive significant results using HI	26	4	1	31	
	Non significant results using HM	62	10	3	75	
		88	14	4	106	
Expecte(	Positive significant results using HI	25.73584906	4.094339623	1.16981132		
	Non significant results using HM	62.26415094	9.905660377	2.83018868		
	Chi - squared	0.041742773				
	p	97.93449%				
	phi	0.019844388				

I generally set	opp	
26	5	31
62	13	75
88	18	106
25.73584906	5.26	
62.26415094	12.7	
0.022565439		
88.05926%		
0.014590459		

I generally s	opp	
4	22	26
10	52	62
14	74	88
4.1363636	21.9	
9.8636364	52.1	
0.0075879		
93.05853%		
0.0092858		

I generally s	opp	
1	3	4
3	7	10
4	10	14
1.1428571	2.86	
2.8571429	7.14	
0.035		
85.15957%		
0.05		

How many tasks do you generally expect your students to complete when Hegarty Maths is set as homework?

		1	2	3	More than 3	\o expectation	
Actual	Positive significant results using HI	9	7	5	10	0	31
	Non significant results using HM	23	33	12	6	1	75
		32	40	17	16	1	106
Expecte(	Positive significant results using HI	9.358	11.698	4.972	4.679	0.292	31
	Non significant results using HM	22.642	28.302	12.028	11.321	0.708	75
		32	40	17	16	1	106
	Chi - squared	11.65064706					
	p	2.01473%					
	phi	0.331529433					

1	opp	
9	22	31
23	52	75
32	74	106
9.358490566	21.6	
22.64150943	52.4	
0.027801511		
86.75763%		
0.016195012		

2	opp	
7	24	31
33	42	75
40	66	106
11.698113	19.3	
28.301887	46.7	
4.2828974		
3.84977%		
0.2010092		

3	opp	
5	26	31
12	63	75
17	89	106
4.9716981	26	
12.028302	63	
0.0002712		
98.68610%		
0.0015995		

More than :	opp	
10	21	31
6	69	75
16	90	106
4.6792453	26.3	
11.320755	63.7	
10.07114		
0.15061%		
0.3082381		

No expectat	opp	
0	31	31
1	74	75
1	105	106
0.2924528	30.7	
0.7075472	74.3	
0.4172698		
51.83025%		
0.0627416		

How much time do you generally expect your students to spend on Hegarty Maths when it is set as homework?

		No expectation	0 minutes per we	) minutes per	) minutes per	minutes per week	
Actual	Positive significant results using HI	1	3	18	9	0	31
	Non significant results using HM	0	9	52	13	1	75
		1	12	70	22	1	106
Expecte(	Positive significant results using HI	0.29245283	3.509433962	20.4716981	6.43396226	0.29245283	
	Non significant results using HM	0.70754717	8.490566038	49.5283019	15.5660377	0.70754717	
	Chi - squared	4.805392543					
	p	30.78545%					
	phi	0.212917571					

No expectatio	opp	
1	30	31
0	75	75
1	105	106
0.29245283	30.7	
0.70754717	74.3	
2.442396313		
11.80957%		
0.151794185		

< 30 minute	opp	
3	28	31
9	66	75
12	94	106
3.509434	27.5	
8.490566	66.5	
0.1178586		
73.13687%		
0.0333448		

30-60 minut	opp	
18	13	31
52	23	75
70	36	106
20.471698	10.5	
49.528302	25.5	
1.2418952		
26.51061%		
0.1082404		

60-90 minut	opp	
9	22	31
13	62	75
22	84	106
6.4339623	24.6	
15.566038	59.4	
1.8252348		
17.66914%		
0.1312219		

> 90 minute	opp	
0	31	31
1	74	75
1	105	106
0.2924528	30.7	
0.7075472	74.3	
0.4172698		
51.83025%		
0.0627416		

Are students directed to watch tutorial videos prior to attempting quizzes?

		Yes	No	
Actual	Positive significant results using HI	27	4	31
	Non significant results using HM	70	5	75
		97	9	106
Expecte(	Positive significant results using HI	28.36792453	2.632075472	
	Non significant results using HM	68.63207547	6.367924528	
	Chi - squared	1.098005887		
	p	29.47041%		
	phi	0.101776943		

Are students directed to make notes while watching tutorial videos?

		Yes	No	
Actual	Positive significant results using HI	28	3	31
	Non significant results using HM	53	22	75
		81	25	106
Expecte	Positive significant results using HI	23.689	7.311	
	Non significant results using HM	57.311	17.689	
	Chi - squared	4.702082889		
	p	3.01261%		
	phi	0.210616411		

Do you use Hegarty Maths to consolidate the learning of concepts that you are currently teaching?

		Never	Rarely	Sometimes	Often	Always	
Actual	Positive significant results using HI	3	1	5	18	4	31
	Non significant results using HM	0	4	29	33	9	75
		3	5	34	51	13	106
Expecte	Positive significant results using HI	0.877	1.462	9.943	14.915	3.802	
	Non significant results using HM	2.123	3.538	24.057	36.085	9.198	
	Chi - squared	11.85442359					
	p	1.84673%					
	phi	0.334416185					

Never	opp		Rarely	opp		Sometimes	opp		Often	opp		Always	opp	
3	28	31	1	30	31	5	26	31	18	13	31	4	27	31
0	75	75	4	71	75	29	46	75	33	42	75	9	66	75
3	103	106	5	101	106	34	72	106	51	55	106	13	93	106
0.877358491	30.1		1.4622642	29.5		9.9433962	21.1		14.915094	16.1		3.8018868	27.2	
2.122641509	72.9		3.5377358	71.5		24.056604	50.9		36.084906	38.9		9.1981132	65.8	
7.469464453			0.2167623			5.1136861			1.7379831			0.0166301		
0.62754%			64.15181%			2.37378%			18.73946%			89.73910%		
0.265455544			0.0452209			0.2196413			0.1280471			0.0125255		

Do you use Hegarty Maths to revise concepts that you have learnt earlier in the year?

		Never	Rarely	Sometimes	Often	Always	
Actual	Positive significant results using HI	0	0	9	21	1	31
	Non significant results using HM	1	7	32	31	4	75
		1	7	41	52	5	106
Expecte	Positive significant results using HI	0.29245283	2.047169811	11.990566	15.2075472	1.46226415	
	Non significant results using HM	0.70754717	4.952830189	29.009434	36.7924528	3.53773585	
	Chi - squared	7.685623353					
	p	10.37972%					
	phi	0.26926916					

Never	opp		Rarely	opp		Sometimes	opp		Often	opp		Always	opp	
0	31	31	0	31	31	9	22	31	21	10	31	1	30	31
1	74	75	7	68	75	32	43	75	31	44	75	4	71	75
1	105	106	7	99	106	41	65	106	52	54	106	5	101	106
0.29245283	30.7		2.0471698	29		11.990566	19		15.207547	15.8		1.4622642	29.5	
0.70754717	74.3		4.9528302	70		29.009434	46		36.792453	38.2		3.5377358	71.5	
0.417269841			3.0979125			1.7191122			6.1210024			0.2167623		
51.83025%			7.83928%			18.98074%			1.33585%			64.15181%		
0.062741597			0.1709549			0.1273501			0.2403025			0.0452209		

Do you use Hegarty Maths by directing pupils to watch tutorials of concepts they haven't learnt in class yet?

		Never	Rarely	Sometimes	Often	Always	
Actual	Positive significant results using HI	2	19	7	3	0	31
	Non significant results using HM	18	28	19	7	3	75
		20	47	26	10	3	106
Expecte	Positive significant results using HI	5.849056604	13.74528302	7.60377358	2.9245283	0.87735849	
	Non significant results using HM	14.1509434	33.25471698	18.3962264	7.0754717	2.12264151	
	Chi - squared	7.729540221					
	p	10.20032%					
	phi	0.270037388					

Never	opp		Rarely	opp		Sometimes	opp		Often	opp		Always	opp	
2	29	31	19	12	31	7	24	31	3	28	31	0	31	31
18	57	75	28	47	75	19	56	75	7	68	75	3	72	75
20	86	106	47	59	106	26	80	106	10	96	106	3	103	106
5.849056604	25.2		13.745283	17.3		7.6037736	23.4		2.9245283	28.1		0.8773585	30.1	
14.1509434	60.8		33.254717	41.7		18.396226	56.6		7.0754717	67.9		2.1226415	72.9	
4.4123991			5.1008603			0.08978			0.0030394			1.2761165		
3.56786%			2.39140%			76.44570%			95.60341%			25.86224%		
0.204025505			0.2193657			0.0291029			0.0053548			0.1097216		

Do you use Hegarty Maths to target gaps in students' understanding following assessments?

		Never	Rarely	Sometimes	Often	Always	
Actual	Positive significant results using HI	1	2	8	16	4	31
	Non significant results using HM	1	7	23	31	13	75
		2	9	31	47	17	106
Expecte	Positive significant results using HI	0.58490566	2.632075472	9.06603774	13.745283	4.97169811	
	Non significant results using HM	1.41509434	6.367924528	21.9339623	33.254717	12.0283019	
	Chi - squared	1.599174302					
	p	80.89405%					
	phi	0.122827318					

Never	opp		Rarely	opp		Sometimes	opp		Often	opp		Always	opp	
1	30	31	2	29	31	8	23	31	16	15	31	4	27	31
1	74	75	7	68	75	23	52	75	31	44	75	13	62	75
2	104	106	9	97	106	31	75	106	47	59	106	17	89	106
0.58490566	30.4		2.6320755	28.4		9.0660377	21.9		13.745283	17.3		4.9716981	26	
1.41509434	73.6		6.3679245	68.6		21.933962	53.1		33.254717	41.7		12.028302	63	
0.424350703			0.2344327			0.2503899			0.9391368			0.3196822		
51.47741%			62.82563%			61.68007%			33.24999%			57.17987%		
0.063271704			0.047028			0.0486022			0.0941264			0.0549169		

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