Navigating Mathematics

Making Sense of Purpose and Activity in Contemporary English Mathematics Education

by

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LIST OF ABBREVIATIONS AND ACRONYMS

A-level	Advanced Level
ALI	Adult Learning Inspectorate
AQA	Assessment and Qualifications Alliance
AS-level	Advanced Subsidiary Level
ATM	Association of Teachers of Mathematics
ATMI	Attitudes Toward Mathematics Inventory
BBC	British Broadcasting Corporation
BIS	Department for Business, Innovation and Skills
BSRLM	British Society for Research into Learning Mathematics
CBI	The Confederation of British Industry
CLAIT	Computer Literacy and Information Technology
CUFCO	Centre Universitaire de Formation Continue d'Angers
CVA	Contextual Value Added
DfE	Department for Education
DfEE	Department for Education and Employment
GCSE	General Certificate of Secondary Education
HLTA	Higher Level Teaching Assistant
ICT	Information and Communications Technology
IEA	International Association for the Evaluation of Educational Achievement
JCQ	Joint Council for Qualifications
MEI	Mathematics in Education and Industry
NAO	National Audit Office
NIACE	The National Institute of Adult Continuing Education
NMC	The Nursing and Midwifery Council
NRDC	National Research and Development Centre for Adult Literacy and Numeracy
NVQ	National Vocational Qualification
Ofsted	The Office for Standards in Education
PISA	Programme for International Student Assessment
QAA	The Quality Assurance Agency for Higher Education
QCA	Qualifications and Curriculum Authority
SAT	National Curriculum Tests
SIMS	The IEA Second International Mathematics Study
STEM	Science, Technology, Engineering and Mathematics
TA	Teaching Assistant
TIMSS	Trends in International Mathematics and Science Study

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DECLARATION OF INCLUSION OF MATERIAL

The data and some of the discussion contained in chapter three formed the basis of my dissertation which was presented as a partial requirement for the award of MA (Educational Research Methods) from the University of Warwick in September 2009. This component of the research has also been presented at a meeting of the BSRLM and written up in their proceedings as Ward-Penny (2009).

The data and discussion presented in chapter four formed the basis of a journal article, referenced herein as Ward-Penny, Johnston-Wilder and Lee (2011).

ABSTRACT

Mathematics education serves a number of purposes within contemporary English society. Many of these concern the learning of knowledge and skills which an individual may need in their everyday life or in a future occupation. Other purposes are predicated instead on the merit afforded to mathematics by society, such that mathematics is used as a benchmark of intelligence or as a gatekeeper to future opportunities in education or employment.

This thesis describes a research project which explores how a variety of learners recognise, navigate and make sense of this range of intents, and how the learners' subsequent understanding informs both their decisions and their personal sense of mathematical purpose. It uses a critical grounded theory methodology to research and report the experiences of four groups of learners: adults returning to the formal study of mathematics after leaving school; undergraduates choosing to leave mathematics behind after completing their degrees; and GCSE students on and beneath the borderline of a watershed C grade.

The results first support specific observations concerning each group then go on to reveal a number of resonances and commonalities which establish how purpose is inferred by, and how purpose influences, learners within contemporary mathematics education. Together the findings demonstrate that the place of mathematics as cultural capital plays a dominant role in steering mathematical trajectories. They go on to illustrate how this role and others impact on mathematical identities, and describe how many learners respond defensively to the current layering of discourses surrounding the purposes of mathematics education. In particular this thesis observes the deployment of minimisation and ego defence strategies, including partitioning mathematical learning, deferring its import and critiquing systems within mathematics education, each of which is advantaged by certain aspects of prevailing practice.

In conclusion this thesis considers critically how these findings might inform both contemporary debates in mathematics education and current trends in pedagogy. It argues in turn for renewed attention regarding how the purposes of mathematics education are considered, balanced and communicated.

INTRODUCTION

The conception of purpose is central to both the outworking and organisation of education. Purpose can offer motivation to learners, provide direction to educators, and has great meaning for policy makers and researchers since “knowing where one wants education to go, ultimately or incrementally, facilitates deciding whether one is getting there effectively” (Cohen 2010, p.3). The import of purpose is particularly assured in the case of mathematics, a subject set apart and awarded a particular respect by the contemporary English government and education system (for instance see Vorderman et al. 2011).

The purposes of mathematics education are however both manifold and multifaceted. As a discipline, mathematics comprises of both highly abstract intellectual activity and practical, content-driven problem solving; the act of mathematical learning can either be dictated as social training in obedience or staged to promote self-realisation (Ernest 1991); and mathematics education itself can be theorised as something which benefits society as a whole (Smith 2004) or as a means by which individuals can progress economically (for instance Crawford and Cribb 2013). Such complexity, together with the situated nature of the purposes of mathematics education, means that learners inhabit a complicated narrative space, constructing then re-constructing figured worlds of mathematics (Holland, Lachicotte, Skinner and Cain 1998) and their own mathematical identities (Black, Mendick and Solomon 2009) against a changing milieu of inferred intent.

This thesis is a study of the experiences and attitudes of an array of groups of learners, reviewed with respect to the purposes of mathematics education. It considers the manners in which these learners have inherited, recognised and responded to the purposes of mathematics education. There exists at present a multitude of pressing concerns in mathematics education regarding, amongst other matters, levels of basic attainment (Rashid and Brooks 2010), shortfalls in recruitment into education and industry (Smith 2004; Reform 2008) and disaffection in school mathematics classrooms (Boaler 2009; Nardi and Steward 2003). In recognition of such concerns and the fact that purpose inescapably informs educational practice, the central intention of this study is to survey, and then question the contemporary effects of the purposes of mathematics education. In this way, the research presented below and the succeeding analysis aim critically to interrogate the contemporary setting of contending philosophies of mathematics education in a manner which speaks to both present debates in education and current trends in pedagogy.

Chapter one begins by asking what the purposes of mathematics might be, and demonstrates how this is a complex question which requires careful consideration. This examination of the goals and roles of mathematics enables the framing of the research contained within this thesis and the construction of the central research questions. Chapter two then establishes the paradigm within which the research is to be conducted, outlining the epistemological assumptions and overarching research methodology of the work.

Chapters three, four and five each present distinct groups of mathematics learners, analysing their experiences and attitudes in light of the previously identified goals and roles of mathematics education. This leads to a synoptic reflection on the results in chapter six which highlights commonalities and thematic links and then argues for particular ways in which supposed purpose, whether stated or implicit, significantly informs both the actions and the experiences of those learning mathematics. The conclusion thus returns to considering critically the aims of mathematics education, and argues how imbalance amongst the aims as they are communicated through certain discourses might currently be leading to adverse consequences within the current systems and outworking of mathematics education.

More than twenty-five years ago, Skemp observed that “not only do we fail to teach children mathematics, but we teach many of them to dislike it” (Skemp 1987, p.3). This comment still has resonance today: in the experiences of many teachers and learners; in the declarations of government reports; and throughout much of the extant research literature. This thesis makes the case that the aims of mathematics education are fundamental, such that a better understanding of the purposes of mathematics education can not only inform current debate but also move to ameliorate present shortcomings.

CHAPTER ONE: PURPOSES OF MATHEMATICS EDUCATION

1.0 The Aims of Education

It is impossible to state definitively the aims of education, since education is both a philosophical and sociological concept and any use of the term invokes a fusion of idealism, theories and culturally situated practices. Hence whilst Plato argues in his *'Republic'* for a system that isolates and favours the most able in a society, Dewey (1897) locates social reform within the school, and Freire (1970) goes further by suggesting that pedagogy should be explicitly designed to emancipate oppressed groups. Equally, whilst ancient thinkers such as Aristotle and modern writers such as Steiner have stressed that practical and theoretical skill should be held in balance, a recent white paper issued by the Conservative government (DfE 2010) suggests that the modern English curriculum arguably valorises academic attainment over vocational success.

These debates and many others are especially salient in the case of mathematics. With respect to social reform, participation and achievement in mathematics education have both been found to be linked to social class, for instance in the work of Cooper and Dunne (1998) who found that social class was related to school children's performance on mathematics test items, or in that of Noyes (2009) who reported social patterns of participation in post-compulsory secondary mathematics. With regard to utility, the tension between pure and applied mathematical training is frequently a matter of debate, as displayed recently in the heated arguments surrounding the proposed introduction of a complementary "use of mathematics" A-level qualification (for instance Educators for Reform 2009; MEI 2009a).

In order to navigate this diversity of intention, it is practical to engage with an initial typology, thus simplifying the situation in a way that allows for further discussion. One common approach (for example within Siegel 2009) is to draw a distinction between 'epistemic' aims and 'moral and political' aims. Epistemic aims are centred on the acquisition of knowledge, and include the learning of knowledge required for employment and industrial practices, the transmission of knowledge to enable the survival and growth of academic disciplines, and the inculcation of cognitive skills. Moral and political aims include the promotion of autonomy, the development of contributory effectiveness within society, and goals particular to societal intentions, such as the promotion of meritocratic educational equality.

Whilst this is a useful initial differentiation in many ways, it can be readily argued that the natures of the aims given above are already very much open to interrogation, and thus there is a demand for more sophisticated categorisation. For instance any epistemic aims invoke, at least implicitly, a concept of truth; in this way they are made more complex by postmodernist sensibilities (Burbules 2009), particularly when the declaration of knowledge and truth is understood as a mechanism of power relations (Foucault 1977). Equally, societal aims such as the promotion of a meritocracy involve further deliberation; in the case of the final aim listed above, the concept of a meritocracy has been challenged by some as being an illusory ideal used to maintain the status quo (for example, McNamee and Miller Jr. 2004).

An alternative extant strategy is to consider separately aims designed to benefit or develop society and aims designed to benefit or develop individuals. However, this distinction is perhaps even more awkward to apply in the case of mathematics education, as the same mathematical facility that benefits an individual's cultural fund

(Bourdieu 1973) is frequently turned to benefit wider society in current economic and technological climates (Roberts 2002).

A full discussion of the aims of general education lies outside of the scope of this thesis. The brief consideration above is offered here only to institute the issues that the aims of any type of education are diverse; that they are socially, culturally and politically situated; that they are open to continual critical questioning; and that they are difficult to categorise. These caveats are certainly true in the case of mathematics education and should be taken to inform the discussion which follows.

1.1 Aims and Goals of Mathematics Education

Many aims have been associated with mathematics education over time by governments, philosophers and practitioners of education. As part of their international review, the Second International Mathematics Survey (SIMS) offered a 'typical set' of such aims, and asked participating teachers to rank them in order of importance:

1. To understand the logical structure of mathematics.
2. To understand the nature of proof.
3. To become interested in mathematics.
4. To know mathematical facts, principles and algorithms.
5. To develop an attitude of inquiry.
6. To develop an awareness of the importance of mathematics in everyday life.
7. To perform computations with speed and accuracy.

8. To develop an awareness of the importance of mathematics in the basic and applied sciences.

9. To develop a systematic approach to solving problems.

(Burstein 1992, p.41)

This is a considered set of aims which is designed to be consonant with many learners' mathematical experience. However, it has been constructed for an international audience and is thus open to a variety of interpretations. The aims are primarily epistemic, whilst moral and political aspects are only presented in a broad sense; there is no detail as to what an "attitude of inquiry" might involve, or to what end it might be directed. It is interesting to note that this exercise produced very diverse results in different countries; Brown (1999) reports that "where US teachers prioritized the importance of mathematics in everyday life together with knowledge, computation and problem solving, the French preferred to nurture intellectual enquiry and the understanding of proof" (p.79). This divergence demonstrates clearly how epistemic aims can be culturally and historically situated.

The official aims of contemporary mathematics education in England are purportedly laid out in the National Curriculum for England and Wales (QCA 2007). Although it is widely understood that mathematics teachers do not follow the official curriculum slavishly (Howson 1991, p.1) and that official positions may involve tacit or assumed goals, the National Curriculum is an extremely meaningful document in a number of respects. First, it informs practice and pupil experience, both directly and through the shaping of textbooks and other intermediary writings. Second, it is an evolving document that reflects the contemporary positioning of mathematics as a school subject in England.

The evolution of the National Curriculum can readily be made apparent by comparing editions. The section of the curriculum document which discusses the purposes of mathematics education at greatest length is the “importance of mathematics” section. Two versions of this section, taken from the last two editions of the National Curriculum, are reproduced here:

> Mathematics equips pupils with a uniquely powerful set of tools to understand and change the world. These tools include logical reasoning, problem-solving skills, and the ability to think in abstract ways.
>
> Mathematics is important in everyday life, many forms of employment, science and technology, medicine, the economy, the environment and development, and in public decision-making. Different cultures have contributed to the development and application of mathematics.
>
> Today, the subject transcends cultural boundaries and its importance is universally recognised. Mathematics is a creative discipline. It can stimulate moments of pleasure and wonder when a pupil solves a problem for the first time, discovers a more elegant solution to that problem, or suddenly sees hidden connections.
>
> (DfEE 1999a, p. 14)

> Mathematical thinking is important for all members of a modern society as a habit of mind for its use in the workplace, business and finance; and for personal decision-making. Mathematics is fundamental to national prosperity in providing tools for understanding science, engineering, technology and

economics. It is essential in public decision-making and for participation in the knowledge economy.

Mathematics equips pupils with uniquely powerful ways to describe, analyse and change the world. It can stimulate moments of pleasure and wonder for all pupils when they solve a problem for the first time, discover a more elegant solution, or notice hidden connections. Pupils who are functional in mathematics and financially capable are able to think independently in applied and abstract ways, and can reason, solve problems and assess risk.

Mathematics is a creative discipline. The language of mathematics is international. The subject transcends cultural boundaries and its importance is universally recognised. Mathematics has developed over time as a means of solving problems and also for its own sake.

(QCA 2007, p.139)

Many of the differences between these two excerpts might be considered of little direct consequence, such as the absorption of ‘medicine’ into science and technology, or the dissolution of ‘the economy’ into ‘business and finance’. However, some alterations suggest a significance beyond mere phrasing or semantics; for instance the 2007 edition stresses that mathematics is “important for **all** members of society” (emphasis mine) and similarly argues for the place of mathematics in personal, as well as public decision-making. That there is an increased emphasis on the individual is further evident in the second paragraph which refers to “pupils who are functional in mathematics and financially capable”. The term ‘functional’ implies a greater stress placed upon the application of mathematics, and is likely designed to invoke the ‘functional mathematics’ qualification that was contemporaneous to this edition

(Edexcel 2010); behind this turn of phrase there is certainly a greater stress placed upon the role of mathematics in the daily life of every individual. The National Curriculum therefore not only suggests the current aims of mathematics education in England, but hints at their development over time.

It is fair to say that the National Curriculum does not just simply state the atomised aims of its version of mathematics education but also indicates wider associated goals, wherein epistemic aims are combined, linked to implicit moral and political aims and then purposely directed. This grouping is almost inevitable when exploring aims within the context of a specific form of mathematics education, and thus *goals*, rather than *aims*, may be a more meaningful unit of analysis for the purposes of critical evaluation laid out in the introduction. However, it should be noted here that the National Curriculum stops short of stating its goals explicitly; most notably, there is no comment on the relative weight of each aim for pupils. Further, there is no discussion of how the goals might be differently relevant to learners; although traditionally the differentiated curricula of England have been accompanied by differentiated aims (Brown 1999) this is not acknowledged here, so it is left to the reader to recognise that individuals, both pupils and teachers, will not engage equally with all aspects of the 'importance of mathematics' statement.

An alternative analysis of the purposes of mathematics education which takes the principle of grouping aims and intents even further can be found in the work of Ernest (1991), who typifies five ideologies of mathematics education. These ideologies are deliberately constructed as an amalgam of aims, philosophies and in some cases pedagogic approaches. Ernest argues (pp.131-3) that philosophies of education regularly begin with theories of society and of the child, so this element can be recognised explicitly in the construction of his model; a similar level of importance is attached to the theory of the assessment of mathematical learning. This is an element of particular contemporary relevance, with current drives towards accountability and reporting in education favouring a curriculum for mathematics that is easily labelled, assessed and reported (Ramaley 2007).

The five ideologies of mathematics education presented in Ernest (1991) are named here, together with their associated ambitions:

- Industrial trainer: seeks to instil a 'back-to-basics' numeracy and aims to use the learning of mathematics as social training in obedience
- Technological pragmatist: wants pupils to attain an appropriate level of 'useful' mathematics ready for employment, measured by industry-centred certification
- Old humanist: aims to transmit the body of mathematical knowledge to ensure the continuation of mathematics as an academic discipline
- Progressive educator: seeks to develop creativity and self-realisation in young learners through mathematics teaching and learning
- Public educator: aims to inculcate critical awareness and democratic citizenship through mathematical activity

(adapted from pp.138-9)

These ideologies explicitly combine epistemic and moral and political aims, and have specific described intents. In many ways they constitute a potentially useful typology for the purposes of this discussion. The ideologies have been designed in light of the British context and thus have resonances with both the wider discussion in section 1.0, as well as with many individuals and organisations which influence policy in mathematics education today. One noteworthy example is the organisation *Mathematics in Education and Industry* (MEI) which aims to support and develop mathematics in a way that is very suggestive of the 'technological pragmatist' ideology. Some of the ideologies can also be seen reflected in the 'importance of mathematics' statement discussed above (QCA 2007, p.139); the idea of mathematics as a "habit of mind… essential in public decision-making" suggests the growing influence of public educators, whereas the claim in both editions that "mathematics is a creative discipline" appeals to the aims of the progressive educators.

Conversely, the strengths of Ernest's model can also be construed as weaknesses. First, although any typology is inevitably over-simplified and idealised (as Ernest himself recognises), Ernest attempts to create a model which tidily coordinates twelve philosophical dimensions within each group. This is highly ambitious, stepping far beyond the conceptualisation of 'goals' outlined above to something much more extensive, and thus it can be argued that Ernest's model thus leads to a number of unhelpful associations. For instance, it puts forward that the 'old humanist' group, which perhaps most closely reflects the university-based academic elite of professional mathematicians, holds to an absolutist philosophy of mathematics which steers their philosophy of mathematics education. This is something of a simplification in light of developing trends in the philosophy of mathematics (Tymoczko 1998). Second, the historical nature of Ernest's observations arguably serves not only to inform his typology but to steer it. The spectre of Thatcher's government and its utilitarian approach to mathematics education (discussed explicitly in Ernest 1991, pp.142-3) has a clear influence on Ernest's construction of the 'industrial trainer' group which might have been tempered in different circumstances. Similarly, the nature of industry has developed greatly in the twenty years since this typology was published, and many mathematical activities in the workplace require a greater technical and mathematical facility than has been the case previously (Hoyles, Noss, Kent and Bakker 2010); in this way many ‘technological pragmatists’ have moved from demanding a simple content-based curriculum to appreciating the value of a techno-mathematical literacy in a manner which has more in common with the aims of the ‘progressive educator’ than before.

Nonetheless, the construction of Ernest’s ideologies offers some triangulation for the aims suggested by both SIMS and the National Curriculum, which in turn supports the construction of a provisional model of contemporary goals, as offered in table 1.1 overleaf. Whilst these goals are neither well-defined nor mutually exclusive, they are sufficiently grounded and described to move this discussion forward. The next part of this chapter will consider each of these goals in detail and review the available evidence relating to the accomplishment of that purpose under the current system. This review is not intended as either a thorough or a rigorous critique, but is included here to introduce, in context, some of the concepts and issues which will become relevant in the following original research and discussion chapters. Section 1.2 will then go on to consider some of the other, social and political purposes which mathematics education performs in contemporary England.

Goal	Primary SIMS Aims	Sample Reference in the National Curriculum Statement (2007)	Connection with Ernest's (1991) Typology
Ensure Numeracy at the Level of the Individual	4, 6, 7	"Pupils who are functional in mathematics and financially capable are able to think independently in applied and abstract ways, and can reason, solve problems and assess risk."	Predominantly *industrial trainer*, elements of *technological pragmatist*
Prepare Learners for Employment and Further Education	4, 6, 7, 8, 9	"...use in the workplace, business and finance… Mathematics is fundamental to national prosperity in providing tools for understanding science, engineering, technology and economics."	Predominantly *technological pragmatist*
Promote Interest in the Use and Study of Mathematics	1, 2, 3, 6	"…its importance is universally recognised. Mathematics has developed over time as a means of solving problems and also for its own sake."	Predominantly *old humanist*
Cultivate Thinking and Problem-Solving Skills	1, 2, 5, 9	"habit of mind… equips pupils with uniquely powerful ways to describe, analyse and change the world… can stimulate moments of pleasure and wonder for all pupils… Mathematics is a creative discipline."	Predominantly *progressive educator*, elements of *public educator*
Develop a Critical Citizenship	1, 2, 5	"essential in public decision-making and for participation in the knowledge economy"	Predominantly *public educator*

Table 1.1 Five Goals of Mathematics Education

1.1.1 Numeracy at the Level of the Individual

Although the term numeracy is widely used within both professional and public communities, it is a problematic concept to define. Coben (2003, p.7) describes it as “a deeply contested concept which may be best considered as mathematical activity situated in its cultural and historical context”; there is resonance here with the discussion above, perhaps consequent from the frequent use of the term ‘numeracy’ to indicate a goal as well as a facility. This ambiguity permits a relatively wide use of the term.

One invocation of numeracy in contemporary governmental practice can be found in the “numeracy skills test” which trainee teachers in England must pass in order to attain qualified teacher status (DfE 2013). This contains a number of specialised items such as questions which involve the interpretation of box-and-whisker plots from within an educational context. The inclusion of context is both nominally and theoretically relevant here as research has shown that a number of basic mathematical practices are performed differently in alternate contexts; in light of this result numeracy practices are often approached from the epistemological position of situated cognition (Lave 1988; Nunes, Schliemann and Carraher 1993). It is thus possible to put forward a notion of numeracy based around contextualised application. However, when taken to its limit, a definition of numeracy that is based around the situated activity of individuals is neither satisfactory nor helpfully descriptive, since it risks admitting a difficulty that also undermines terms such as ‘functional mathematics’ and ‘everyday mathematics’. Any use of a criterion that depends so fully on individual contexts risks labelling all mathematical activity as ‘numeracy’, as even the most advanced group theory might be considered to be everyday activity by a research mathematician. Conversely, an extreme insistence that numeracy is a common core of mathematical knowledge and understanding that is useful to everyone admits a reductive argument, which boils numeracy down to nothing beyond elementary counting and the most simple manipulation of number (Ward-Penny 2010). For the purposes of this discussion, numeracy will be understood to be a mathematics-based parallel to literacy; a level of mathematical facility that is evident across the population with a sufficient commonality and frequency; and a range of mathematical skills that is often made necessary but not fully demarcated by context. This conception is still somewhat broad and lacking in rigour, but it is sufficient for the purposes of this discussion and is consonant with the definition of numeracy outlined in official discourse, such as that given in the Moser report: the ability "to use mathematics at a level necessary to function at work and in society in general" (DfEE, 1999b).

The majority of pupils within the English education system encounter numeracy content within their wider learning of mathematics. Skills such as reading the time from 12- and 24-hour clocks, using scales on measuring instruments and conducting basic calculations involving money are included in both the National Curriculum and GCSE specifications. The grade descriptor for GCSE Grade F offered by the examination board AQA is highly consonant with the definition of numeracy offered above:

> "…They complete straightforward calculations competently with and without a calculator. They use simple fractions and percentages, simple formulae and some geometric properties, including symmetry. Candidates work mathematically in everyday and meaningful contexts. They make use of diagrams and symbols to communicate mathematical ideas. Sometimes, they check the accuracy and reasonableness of their results…" (AQA 2009, p.29)

It would be fallacious to equate fully qualification at the level of a GCSE Grade F with numeracy for a number of reasons, not least because the outlined content of each specification contains items, such as knowledge of the angle sum of the triangle, which are not typically called upon in everyday adult living. Equally a candidate can achieve a Grade F in GCSE mathematics in a multiplicity of ways, since the single summative grade awarded can disguise a range of ability profiles. Still, it is reasonable to propose that in the majority of cases a candidate with a fair functional numeracy would meet enough of the criteria to attain either a Grade F or a higher grade on a GCSE exam; therefore it seems to be valid to use the proportion of pupils failing to achieve this standard as one first-order approximation of the number of pupils leaving school without a fair standard of functional numeracy.

	E Grade (%)	**F Grade (%)**	**G Grade (%)**	**Unclassified (%)**
2011	10.9	7.5	3.9	1.6
2012	10.1	7.2	4.4	1.8

Table 1.2 Lower end of GCSE Mathematics Results, 2011-12 (JCQ 2012)

In this way the data presented in table 1.2 suggests that between 5% and 7% of each cohort could be considered to be functionally innumerate. This proportion, calculated as the number of candidates attaining a G or a U grade, consisted of approximately 41,900 individuals in the 2012 cohort. Again, it should be noted that this is a first-order approximation. This data serves as a snapshot of each cohort at one moment in time; some of these learners undoubtedly went on to retake their exams at a later date and attained a higher grade before leaving education. However, it should also be recognised that a small number of candidates are judged by schools to be extremely weak and are not entered for the GCSE, and so this figure could actually be an underestimate. Related research would appear to suggest that this is indeed the case.

In their review of literacy and numeracy for 13-19 year olds, Rashid and Brooks (2010) conduct a meta-analysis of eight relevant surveys, including multiple iterations of TIMSS and PISA. Through this they identify a base category of a:

"very basic competence in maths, mainly limited to arithmetical computations and some ability to comprehend and use other forms of mathematical information. While this is valuable, it is clearly not enough to deal confidently with many of the mathematical challenges of contemporary life. From the various surveys at age 16+ it can be estimated that about 22% of young people in England are at this level" (p.71).

Rashid and Brooks go on to state that this proportion compares poorly with many other industrialised countries. Although this finding is subject to a number of methodological weaknesses inherent to meta-analyses, it is a more thorough and certainly a more longitudinal estimate of levels of poor numeracy than a simple extrapolation from GCSE attainment. The disparity between the earlier estimate of 6% and the estimate of 22% can be understood in a number of ways. It might be suggested that many candidates who achieve a Grade E or F at GCSE learn mathematics in a way that helps them to pass an examination but not to develop a lasting numeracy; further, there is scope for claims that some parties take advantage of modular examinations at GCSE to inflate grades.

Further evidence that the proportion of innumerate adults is close to one quarter can be found in both historic and contemporary research. The adult study of mathematics has been an increasingly visible and politicised field under the 'New Labour' government (Hamilton and Hillier 2006) with many new initiatives being introduced to promote the study of ‘basic skills’. This surge was influenced by the findings of the Moser report (DfEE 1999b) which had reported worrying high levels of innumeracy. The offered estimate therein was that 23% of the population had ‘very low’ levels of numeracy, a figure which is remarkably close to that suggested by Rashid and Brooks eleven years later. This approximate figure was again reported in the 2011 Skills for Life survey (BIS 2012) which offered that 24% of respondents failed to perform at the key standard of Entry Level 3 (p.32).

The similarity between the proportions noted above deserves some comment; if the Moser report is understood to be corroborative of the more recent findings, this in turn implies that the intervening adult numeracy initiatives have not been as successful as might have been hoped. There are many possible reasons why this might be the case. One possibility is that there are problems with the quality of teaching in the sector; certainly subsequent inspection reports such as Ofsted/ALI (2003) have stated that there remains a greater need for expertise in the teaching of numeracy, and that many courses promote rote learning above developing understanding of the concepts involved (p.14); although it can be argued that there is a place for rote learning in mathematics, it is questionable whether a reliance on learning through repetition can limit learners’ later ability to apply mathematical ideas in real-life contexts. There are also a number of outstanding questions about exactly who is studying numeracy; one survey conducted by the National Institute of Adult Continuing Education claimed that “those in the highest socio-economic groups were twice as likely to study as those in the poorest” (BBC News 2009).

The evidence presented above strongly suggests that the current mathematics education system is not meeting its goal of equipping all learners with an apposite level of numeracy, and that a significant fraction of the population could be considered innumerate. Although it is arguably inevitable that there will always be some learners who will consistently struggle with mathematics, the proportions discussed transcend this minority and compare poorly with international levels of numeracy. Similarly, whilst there have been some advances in the provision of adult numeracy courses, the outworking and practices involved are subject to further meaningful criticism.

This failing has consequences. Reports such as Bynner and Parsons (1997) have illustrated that poor numeracy has a harmful effect on both career prospects and job performance; more recent research (including Parsons and Bynner 2006; Carpentieri 2008) goes further, suggesting that poor numeracy has a greater impact on employment than poor literacy, particularly for women. Furthermore, whilst it can be argued that the current rate of poor numeracy has a limited effect on the economic performance of the country as a whole (Robinson 1998), at the level of the individual poor numeracy has been linked with a number of social costs associated with unemployment and remedial education; the Every Child a Chance Trust (2009) estimates the annual bill for these costs at over £2 billion. In short, the functional innumeracy that persists under the current system compromises life chances and has social and economic implications.

1.1.2 Preparation for Industry and Employment

The concerns about 'basic skills' discussed above remain relevant when evaluating the second identified goal of mathematics: preparing learners with the mathematical knowledge and skills that they are likely to need for their future employment. This overlap is prominent in criticisms issued by employers, such as claims that schools are failing to equip their pupils sufficiently, and complaints that companies are forced to provide supplemental training in basic skills, often at great cost. One such report (CBI

2010) suggests that these concerns are widespread, holding that 63% of employers want schools to imbue learners with better standards of literacy and numeracy (p.10).

It can be argued that the goal of preparing learners for industry and employment is more nuanced than the goal of equipping all learners with a basic level of numeracy, since the mathematical demands of individual jobs are rarely codified and ever developing. Nevertheless, it is possible to make some steps towards a broad evaluation by considering different skill levels required in occupations and different educational pathways.

In the first instance, learners intending to apply for semi-skilled jobs are most likely to aim for a GCSE qualification in mathematics. The achievement of a C grade in this examination has arguably become a *de facto* indicator of a fair level of quantitative literacy and logical thought that stretches beyond basic numeracy. The employment of this curricular shorthand is easily criticised and will be discussed further in section 1.2, but it remains true that a C grade in GCSE mathematics is widely used as a gatekeeper qualification, managing entry to a vast range of opportunities in employment and further education, as well as serving as an indicator which schools themselves are judged by. It is therefore worth noting that despite years of targeted investment and effort by governments and schools, less than 59% of the 2011 and 2012 cohorts achieved a ‘C’ grade or higher (JCQ 2012).

As with the discussion of the GCSE grades in section 1.1.1, it is important to note that this is only a first-order approximation. On the one hand, the reported achievement rates only comment on the proportion of learners who attain the grades by age 16 and do not incorporate learners who succeed later on in life; conversely, they do not betray the influence of observed grade-boosting strategies which schools employ, such as modular entry and scheduled retakes. The relevance of the GCSE as a preparation for employment has also been criticised (for instance within Hoyles, Morgan and Woodhouse 1999). It may then be valuable also to consider some of the other mathematics qualifications which learners may encounter.

Some of the learners who do not sit the GCSE in mathematics instead take a functional mathematics exam. The examination board Edexcel explains that the "Functional Skills Mathematics qualifications are designed to give learners the skills to operate confidently, effectively and independently in education, work and everyday life. They have been created in response to employers' perceptions that many learners are not achieving a sufficiently firm grounding in the basics" (Edexcel 2010, p.3). In this way these qualifications could be considered as intending to build upon basic numeracy practices in a way that is largely consonant with the agenda of the technological pragmatists (Ernest 1991). Functional mathematics qualifications could be taken within a wider vocational course of study, such as the short-lived and now defunct 14-19 diplomas.

Unfortunately, despite the scope and potential of this approach, the delivery of functional mathematics has been largely unsuccessful in schools, both currently and historically. Ofsted (2010), in their review of the diploma qualifications, commented that the delivery and integration of functional skills stood out as a particular weakness. This resonates with similar criticisms levelled at the teaching of mathematics within a previous vocational qualification, the NVQ (Wolf 2000).

This failing is indicative of a wider concern within mathematics education. Despite the efforts of researchers, authors and curriculum designers, there are persistent challenges and concerns about bringing realism into the mathematics classroom for the majority of learners. The 'applied' mathematical activity experienced by most learners is largely dominated by ersatz activity supported by 'curricular fictions' (Hall 1999); contexts are replaced by 'cons' which do not authentically relate to the pupils' worlds and thus imply meta-messages about the relevance of mathematics (Ward-Penny 2010). These are not new observations, and they are present in many key reviews of mathematics education (for example Cockroft 1982; Smith 2004); for instance the 'Half our Future' report (Newsom 1963), designed to evaluate the schooling of pupils of "average and less than average ability" comments rather dryly that "the areas of carpets can be found too often" (p. 148). Further to this it can be argued that as mathematical learning becomes more diverse and context-led it inevitably moves away from a centrally moderated syllabus; in her recent review of vocational education Wolf (2011) notes that the tension between using a "wide range of realistic contexts" and preparing students for a standardised assessment is "not a circle which can be squared" (p. 171).

Further limitations on the effectiveness of current mathematics education in preparing learners for employment may be imposed by the changing nature of occupations. It has long been recognised (for instance Clayton 1999) that the increasing role of ICT is causing a shift in the mathematics required in many workplaces, and this has led writers such as Hoyles et al. (2010) to claim that many semi-skilled jobs now require a techno-mathematical literacy which is not being properly addressed by the current school curriculum, and that there is a perceived "'skills' gap in the UK workforce for understanding and dealing with technical information expressed in symbolic form" (p.2). A related argument is that the skills of using ICT mathematically and the development of a capacity to model are only sporadically taught, and often only to groups aiming for the higher grades. The epistemological position of situated cognition (Lave and Wenger 1991) is again relevant here, as it suggests most strongly that the artificial nature of classroom mathematics undermines the goal of equipping learners for the workplace, where solutions are constructed in the course of action and activity shapes thought (Noss 2002).

Finally in this section it seems critical to consider whether the current mathematics education system in England is equipping enough learners for occupations that require a high level of mathematical facility. Such jobs are often grouped under the ‘STEM’ umbrella (science, engineering, technology and mathematics) and this terminology is common in contemporary official discourse. The Confederation of British Industry reports that 45% of employers are having trouble finding employees for STEM posts (CBI 2010, p.7), and reports such as Reform (2008) corroborate that there is a significant shortage in key sectors such as finance. This conclusion is also clear in official discourse; the Roberts Report (2002) and the subsequent Council for Industry and Higher Education STEM Review (Smith 2007) both recognise this shortfall, with the latter report observing that “the supply chain of STEM graduates remains leaky at all the decision-making joints and the supply emerging is inadequate in key areas to meet business needs” (p.3). Both of these reports comment on some of the issues surrounding this deficit; of particular note for this discussion is the recognition that there is a shortage of qualified teachers, and the observation that there is a particular shortage of female mathematics graduates.

In summary, the current mathematics education system in England does not appear to be adequately preparing many students for mathematical activity in the workplace. Poor levels of basic skills continue to impact negatively upon a significant number of employees and employers; mathematics education in school has not been constituted and is not being conducted in such a way that the demands of modern, changing workplaces are being met; and STEM careers, despite being identified as a national priority, continue to report widespread problems with training and recruitment. Although the diverse nature of employment and industry does not allow any definite judgement, it would appear that the current system is failing to meet the goal of preparing an adequate number of learners for the modern workplace in a substantive sense.

1.1.3 Promotion of Interest in Mathematics

The third goal of mathematics education listed above is the promotion of interest in the practice and study of mathematics. Whether mathematics is conceptualised as an absolute body of discovered truth or as an evolving, culturally developed system of logic and reasoning, an argument can be made that mathematics is a field of human intellectual endeavour which should be valued in its own right, as well as for its applications and effectiveness (for instance Hardy 2005). It follows from this position that mathematics education should be conducted in a manner which cultivates a general interest in mathematics and encourages learners to continue with its study, thus ensuring the continuance of the field. The evaluation of this goal requires an examination of both reported attitudes towards mathematics and levels of participation.

It is problematic to summarise the extant research concerning learners' attitudes towards mathematics; opinions are neither uniform nor static, and research often explores affective variables as they relate to specific aspects of teaching and learning, or measures affect within specific subgroups of learners. Nevertheless, there is a growing body of evidence which clearly holds that learners do not see mathematics as interesting. In one survey of 2000 secondary school children (BBC News 2004) mathematics was determined to be the second most boring school subject, and mathematics teachers were labelled the 'most evil'; more recently Jin, Muriel and Sibieta (2011) found that mathematics was the least favourite subject of pupils aged 14. Negative opinions have also been expressed by adults; for instance, the three most frequently expressed attitudes in Lim and Ernest's (2000) research into public images of mathematics were that mathematics was difficult, that mathematics was boring, and that mathematics caused anxiety.

Such pejorative perspectives would appear to be inflated by aspects of current practice in mathematics education. Research such as Nardi and Steward (2003) associates poor attitudes to the subject with dominant pedagogic elements of the mathematics classroom, notably the practice of rote-learning and a depersonalised presentation of the curriculum. Picker and Berry (2000) offer that pupils' attitudes to mathematics are further steered by their lack of appreciation of the purpose of mathematics; in their research into lower secondary pupils' images of mathematicians they report that "as far as pupils of this age are concerned, mathematicians are essentially invisible" (p.73). Although it is proper to note once more that many pupils do engage positively with the subject, and that research often points towards instances of good practice, it is fair to say that for many pupils their experiences are failing to encourage interest in the study of mathematics, and may even be doing the opposite.

A similar mixed picture emerges from the data surrounding the issue of participation in the study of mathematics. Whilst recent years have seen some increase in the number of candidates studying post-compulsory mathematics in the form of the mathematics A-level, there is evidence of a gradual decline in uptake since the late 1980s (Matthews and Pepper 2007). Similarly, although mathematics was commendably the second most popular A-level in 2010 (The Telegraph 2010), this figure should be understood as partly consequent of the economic return associated with the qualification (Dolton and Vignoles 2002), and it should be stressed that there are still concerns that not enough students are choosing to study mathematics. Further to this, participation also seems to be linked inequitably to gender and other social characteristics (Noyes 2009).

As was the case with attitudes towards mathematics, there is an increasing awareness that the issues surrounding participation are compounded by aspects of current practice in the mathematics classroom. Research into the uptake of A-level mathematics, such as Brown, Brown and Bibby (2008) demonstrates that many potential candidates move away from the study of mathematics in a very definite, vehement way, citing as reasons that it is too difficult, boring, and that they do not enjoy the subject. These concerns persist into A-level; Noyes and Sealey (2012) observe in their research that the rate of attrition is higher in A-level mathematics than in almost every other subject. They go on to demonstrate that attrition rates vary substantially between schools, suggesting that the quality of teaching can be very influential in steering learners' decisions.

In contrast to many of these findings, there has been great success in recent years with the provision of A-level further mathematics in more schools, and in 2010 further mathematics was the fastest growing A-level (The Telegraph 2010). This success could be used to argue that mathematics education is successfully equipping an elite core of pupils to go on and study mathematics at university, and in this sense mathematics education is meeting the third goal. However, this achievement is partially diluted by further problems which emerge at university level. Alongside further instances of standard attrition, a significant number of undergraduates studying mathematics are becoming disaffected in higher education and are choosing to leave mathematics behind after graduating (Wiliam 2005; Burton 2004).

In summary, although recent years have seen some significant improvements, and a core of students are studying mathematics successfully to a high level, there are a number of substantial ways in which the current mathematics education system is failing to meet this third goal. There would appear to be an extensive negative attitude towards mathematics amongst both learners and the general population, and rates of participation in post-compulsory study remain questionable and inconsistent despite concerted levels of intervention and political attention.

1.1.4 Development of Thinking and Problem-Solving Skills

The final two goals of mathematics education as outlined above are perhaps the most problematic to measure as they both involve the inculcation of abstract thinking skills. The first of these takes in the development of logical thinking and problem-solving skills.

Problem-solving has long been held as being both critical and vital to any meaningful mathematics curriculum. Pólya (1962) holds that "the first and foremost duty of the high school in teaching mathematics is to emphasize *methodical… problem solving*" (pp. xi-xii) whilst Halmos (1980) goes as far as to claim that "what mathematics *really* consists of is problems and solutions" (p.519). In an even broader sense, it can be argued that to be able to think mathematically is to be better able to understand the world, to apply the "science of pattern" (Hoyles and Noss 2000, p.164) and to be able to grasp and manipulate increasingly abstract concepts which have relevance in the real world, such as rates of change of rates of change (Dörfler 1999, p.71). Tikly and Wolf (2000) argue that schools must teach learners how to think in these ways, and that teaching principally content at the secondary school level, together with a limited range of pre-determined mathematical procedures "is not only inegalitarian, but a recipe for economic stagnation" (p.11). This view is resonant with wider moves in education which conceive of schools as places of epistemic apprenticeship, rather than centres for pre-determined training (for example Claxton 2008).

Current practice in English mathematics education offers some notable accomplishments in this area: the official discourse of the national curriculum (QCA 2007) recognises the importance of mathematical thinking skills and promotes their development, and there are a number of successful initiatives such as the national challenges run by the United Kingdom Mathematics Trust, which are centred on problem-solving challenges. The comparison afforded by the Trends in International Mathematics and Science Study (Sturman, Ruddock, Burge, Styles, Lin and Vappula 2008) suggests that English pupils aged 13-14 typically perform at an above average level when tested on mathematical cognitive domains as well as on most content domains, although the 2007 test exhibited lower skills for 'applying' than for 'knowing' and 'reasoning' (p.69). Notwithstanding these observations there are a number of persistent concerns in this area.

First, there is a recurrent argument surrounding the actual place of problem-solving in the classroom. Practice is inevitably steered by the style and content of the GCSE assessment, and at the time of writing this could be criticised as favouring shorter items based around recall and procedure rather than longer items involving authentic problem-solving. Second, there is a growing body of research which questions whether problem-solving is taught equally. Morgan (1998), in her analysis of mathematics textbooks, has demonstrated that foundation pupils are often located outside of the community and presented with a restricted range of tasks that typically only require lower order thinking skills; this restriction is also typical of many classrooms (for instance De Geest, Watson and Prestage 2003). Of critical concern is the research of Anyon (1980; 1981) which points towards a class bias in the presentation of thinking skills. Hence whilst problem-solving is handled somewhat respectfully in official discourse, the power and practice of mathematical thinking is not always presented to pupils equally or effectively, leading Hoyles and Noss (2000) to comment that "far too many people whose lives – whether they like it or not – have been revolutionized by mathematics, imagine that its high point is long division" (p.157).

1.1.5 Growth of a Critical Citizenship

The facility of problem-solving discussed above in section 1.1.4 can be understood as contributing to the growth of pupils' critical citizenship. It is in this sense that Mellin-Olsen (1987) argues that mathematics education is immediately politicised; through deciding how to give pupils chances to develop mathematics tools with which to interpret and question the world, teachers automatically enable or frustrate their pupils' ability to engage critically with their society and surroundings. Although this process of empowerment can be conceptualised within a more radical model of education (for example Fielding and Moss 2011) such a shift is not necessary; it is independently true that the modern citizen requires mathematical skills to engage with many contemporary issues, from numbers reported in the millions and billions to subtler issues of statistical and probabilistic literacy (Blastland and Dilnot 2008). Such concerns are "political since 'man is a social animal' – not political in the sense of indoctrination" (Mellin-Olsen 1987, p.38).

A growing awareness of the de facto political potency of mathematics education has been revealed through calls for opportunities to integrate an explicit critical component into mathematics teaching and learning (for example, Skovmose 1994; Frankenstein

1998; MacKernan 2000). Gutstein (2006) talks about ‘reading and writing the world with mathematics’, and claims that this is an essential component of a pedagogy which enables social justice, as well as political participation. However, there is very limited evidence that this trend is being recognised at present in either official discourse or pedagogy. Although the English national curriculum (QCA 2007) does hold that all subjects should contribute to the moral development of pupils, there is little specific guidance offered on how this might be applied in the case of mathematics. Further, dominant pedagogic approaches reported in research such as Nardi and Steward (2003) typically limit the skills of literacy and oracy that would likely be central to any critical application of mathematics (Morgan 1998; Lee 2006; Alexander 2008). In summary it would appear that the goal of developing a critical citizenship through mathematics education, whilst fundamental to Ernest’s (1991) public educators, has yet to be fully realised or substantially reflected in official discourse.

1.2 Aims, Goals, Roles and Ideologies of Mathematics Education

The discussion above has delineated then examined in turn five purposes which have been understood as goals of mathematics education. Still mathematics education serves a number of purposes which have not yet been considered. These purposes relate in various ways to the power involved in mathematics education and potentiated as mathematical qualifications (Valero 2007).

Section 1.0 briefly discussed that education has long been recognised as a tool which governments can use to manage and direct a populace; for instance Ernest (1991) goes as far as to call education an “ideological state apparatus” (p.248). This understanding forces an acknowledgement of the political purposes of education, which are here and henceforth termed as *roles*, to distinguish them from the previously described *goals*.

Whilst the goals of education are frequently explicit, present in official discourse and instituted by society, the roles of education are more commonly implicit, enacted through imposed structures and traditions, and embedded in (or perhaps imposed on) society. For clarification a simplified visual image of this contrast is offered in figure 1.1 below to show how the terms *aims*, *goals*, *roles* and *ideologies* are intended to be understood in the following discussion.

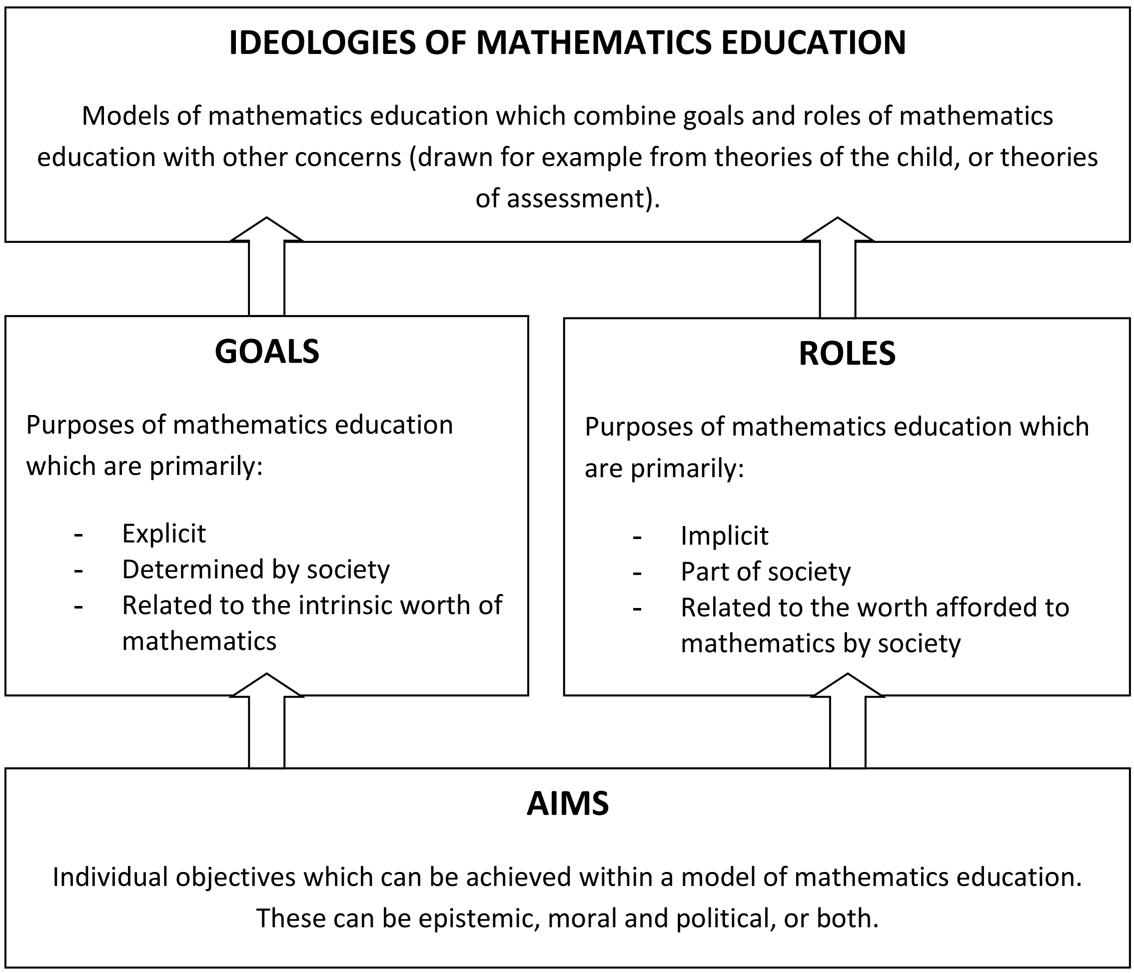


Figure 1.1 A Hierachical Model of Purpose within Mathematics Education

The political dimensions of purpose are often particularly prominent in the case of mathematics education; Popkewitz (2004) even posits that “mathematics is one of the high priests of modernity. Mathematics education carries a salvation narrative of progress into the upbringing practices of schooling” (p.251). The political and sociological history of this narrative is complex. It is possible that mathematics has been allied with notions of progress by tradition, the association between mathematics and politically valued industries, or even philosophical biases; as Lerman (1990) points out, mathematics can be seen as “the last bastion of absolutism” (p.54) and so might be favoured by traditionalist thinkers as a marker of intellect over disciplines which appear to favour relativism over rigour. A full discussion of the historical development of this relationship, and any questions of merit, lies outside of the scope of this thesis; it is required here only to recognise that contemporary mathematics education serves political purposes within the mechanisms of the state. The most visible of these purposes is the role of mathematics as a gatekeeper qualification.

1.2.1 Social and Cultural Reproduction

It has often been commented upon that education plays a role in the reproduction of societal structures and values, perhaps most famously by Bourdieu (1973). Education for Bourdieu is “the mechanism through which the values and relations that make up the social space are passed on from one generation to the next” (Webb, Schirato and Dannaher 2002, p.105). Key to this understanding is the notion that the accrual of qualifications establishes an individual’s “cultural capital”: recognised markers of culturally authorised attributes and skills which signify success and facilitate progress within a society. Bourdieu sees mathematics qualification as a special form of cultural capital:

> "Often with a psychological brutality that nothing can attenuate, the school institution lays down its final judgements and its verdicts, from which there is no appeal, ranking all students in a unique hierarchy of all forms of excellence, nowadays dominated by a single discipline, mathematics."
>
> (Bourdieu 1998, p.28)

Whilst Bourdieu here is writing about the French educational system, a similar claim can be levelled at the contemporary English system. A C grade in GCSE mathematics is an extremely potent qualification, as it acts as a gatekeeper to a vast array of opportunities in employment and higher education. This role has led to a number of changes in practice and policy: from the move in 2006 from a three- to a two-tier GCSE which technically allows all students taking the exam to attain a 'C' grade to the recent recommendation that all pupils who fail to achieve a 'C' in GCSE mathematics should be forced to retake the exam if they continue in education (Wolf 2011). The import of the GCSE mathematics qualification is widely accepted, and it stands as a definite instance of cultural capital.

The borderline between a 'C' and a 'D' grade in GCSE mathematics can however be criticised as being somewhat arbitrary. Whilst GCSE examinations were originally intended to be criterion-referenced (Pring 2013), in contrast to the norm-referenced O-levels, examination boards are now free to manipulate mark boundaries in response to the perceived relative difficulty of each paper; this re-introduces norm-referencing and allows for the management of grade proportions. This is particularly contentious in light of the fact that the same grades which are used to assess pupils are also used to assess schools, and further, governmental policy decisions (de Waal and Cowen 2007). Criticism can also be gathered from the simple fact that many of the occupations and courses which require a C grade in mathematics use little to none of the mathematical content studied.

The problematic nature of borderlines in high-stakes assessment has long been recognised (for instance Cockroft 1982, paragraph 446). However, it is the consequences of this borderline which are of relevance here. Noyes (2007, p.4) calls upon Durkheim's use of the terms 'sacred' and 'profane' to describe the effect of the 'C' grade in mathematics; Sells (1973) talks of mathematics as a 'critical filter' which screens learners for prestigious careers and discriminates between social groups; and Stinson (2004) talks explicitly about mathematics being used as a tool for social stratification in America. Such arguments can be extended to propose that mathematics plays an acute role in contemporary English society wherein hierarchies of mathematics, ability and social class work together in perpetuating class structure (Ernest 1991, p.255). In particular, it can be posited that pupils from wealthier families have access to more successful schools, and additional support such as private tuition. This safeguards their attainment of the grade required, and maintains their access to higher paid jobs and wider opportunities in further education. Conversely, pupils from poorer backgrounds are less likely to end up in schools with high academic success rates, and are thus more unlikely to attain this particular piece of cultural capital which could enable social mobility. This repression constitutes an instance of what Bourdieu would term 'symbolic violence'. Corroborative evidence for compounding, hidden symbolic violence in mathematics education can be found in research such as Cooper and Dunne (1998) who demonstrated that the formatting and presentation of test items in mathematics disadvantaged working class students.

Further confirmation of the reproductive role of mathematics comes from higher qualifications in mathematics. The main post-compulsory qualifications in mathematics are A-levels in mathematics and further mathematics. Noyes (2009) has demonstrated that there is some relationship between social class and participation in A-level mathematics, although this is somewhat clouded by other variables. The evidence is a little clearer in the case of A-level further mathematics, a qualification increasingly being used as a necessary requirement for admission to some of the more prestigious mathematics undergraduate degree courses. Despite some efforts to promote the qualification across the country, further mathematics is still less commonly offered by state schools than by independent and grammar schools (Ward-Penny, Johnston-Wilder and Johnston-Wilder 2013, p.6). This suggests that Wolf's (2000) description of the teaching of further mathematics as the 'skilling' of the upper classes still has relevance and that inequality in access to mathematical qualifications is limiting social mobility.

1.2.2 Mathematics as a Monitor of Performance

Another role of mathematics education in the current educational system is to reflexively assess the performance of various components of the system itself. The same qualifications and grades which are used to label and manage pupils are also used to assess the performance of the schools, and beyond that the success of any government-led programmes of improvement. The contentious nature of this situation has already been outlined briefly above, but this compound purposing of results has a number of allied consequences at school level.

Goldstein and Leckie (2008) opine that "some schools… concentrate excessively on "borderline" pupils, who might just scrape the C grade which counts towards the school's score" (p.69) The likelihood of this occurring can only have been increased by the introduction of the ‘5 A* to C including English and Maths’ indicator. Whilst the former schools minister Jim Knight claimed that this indicator was designed to ensure parents can see how schools are doing on the basics (Directgov 2007), no performance monitoring “scheme can be viewed in isolation from the incentives – designed or accidental – that exist alongside it” (Bird et al. 2005, p.20). High-stakes measurement of this kind will always have consequences, as well as “the potential to conflict with priorities and values held by professionals” (ibid., p.21). This role of mathematics education is thus one of the most controversial, most visible, and most likely to be held in tension with other purposes.

1.2.3 Mathematics as a Marker of Intelligence

One final role which will be considered in this review is the propensity with which facility with or achievement within in the field of mathematics is sometimes used as an indicator of a typically fixed general intellectual ability. Mathematics has long been associated with intelligence, for instance in the primacy of logico-mathematical tasks in the construction of IQ tests, and despite growing regard for alternative models of intelligence (such as Dweck 2000; Gardner 2004) public perception often continues to ally mathematical ability with intellectual aptitude. Whilst beliefs about intelligence are ultimately personal, this association can be repeatedly inferred at a larger scale from the popular media through its use of the largely pejorative figure of the ‘nerd’ or ‘geek’ (Farnall 2003), a stereotype which arguably continues to be deployed as a result of the relative public invisibility of mathematicians and their work (Picker and Berry 2000).

The development and history of this role is complex and undoubtedly interrelated to the other roles described above. It is likely that the widespread philosophical understanding of mathematics as an undiluted, absolute field of study (Lerman 1990) has encouraged its use as a measure for abstract, general intelligence. A fuller critical reading might go on to consider whether the continued propagation of this association has advantaged male learners via psychological mechanisms such as stereotype threat (for instance Beilock, Rydell and McConnell 2007), and that this advantage may have played a part in its promotion. However, it is sufficient for this review to note that the image of mathematics as being reflective of general intellectual capacity exists and is sufficiently common that it might impact upon learners' experiences of and opinions about mathematics.

The roles of mathematics education, using the term as defined in section 1.2, are perhaps harder to demarcate or distinguish than the goals of mathematics education. To this end, and for reasons of space, no working typology parallel to table 1.1 is offered here. Nonetheless, it is held to be both apparent and imperative that mathematics plays significant roles in the reproduction of social strata; in enabling and frustrating social mobility; and through examinations and qualifications as articles of cultural capital. To this end it is proper to discuss both the goals and roles of mathematics education in any critical appraisal or research.

1.3 Interactions between Goals and Roles and the Central Research Questions

The explication of the goals and roles of contemporary mathematics education above has given rise to a critical line of inquiry: how might these goals and roles of mathematics coexist and interact in contemporary English mathematics education? The definitions constructed above express that both collusion and conflicts of interest are inevitable; the aims of mathematics education transcend both the epistemic and the political, whilst the products of mathematics education have simultaneous consequences at the levels of the individual and their society. Individuals might even be advantaged or oppressed by the same force at different points in what Noyes (2007) terms as their mathematical trajectories.

The central research questions of this thesis can thus now be constructed as follows:

- How do the experiences and mathematical trajectories of learners reflect the competing goals and roles of mathematics education?
- How do learners navigate and make sense of competing or co-existing goals and roles of mathematics education? In particular, how do they make sense of their own mathematical purpose?

In each of these questions the terms ‘goals’ and ‘roles’ are used in the senses outlined above. The next chapter will operationalise more fully these questions, by establishing the epistemology and outlining the methodology of this work.

CHAPTER TWO: ESTABLISHING THE FIELD OF INVESTIGATION

2.0 Introduction

The foregoing discussion has argued for both the urgency and import of evaluative research into the purposes and performance of contemporary mathematics education. However, the possible lines of investigation and analysis are diversely supported by different paradigms of educational research, and thus a theoretical basis for this work will be established before proceeding.

This chapter will describe the epistemological position of this thesis by presenting a very brief summary and history of critical theory as it pertains to mathematics education. It will go on to consider some of the ontological issues that are invoked by the wording of the research questions, and then finally present the overarching critical grounded theory methodology constructed for this research.

2.1 Critical Theory

The research questions of chapter one do not sit comfortably within all educational paradigms. Most notably the range and intent of this research contradict some of the tenets of a positivist paradigm: ethical and pragmatic constraints mean that there is limited scope for empirical testing, and the questions themselves challenge the notion that science is a value-free activity (Delanty 2005). Yet whilst the policies and practices of contemporary mathematics education cannot be conclusively assessed in a positivist sense, they can be meaningfully evaluated through the use of critical theory. Indeed, the prior arguments offer that not to do so would be to risk relegating the exercise of accountability partially or fully outside of the scope of academic concern.

Critical theory is a paradigm which proposes a multi-disciplinary survey and critique of the elements of society, holding at its core that all social phenomena and interactions, including the act of research, are socially and historically embedded (Gibson 1986, p.4). It is "explicitly prescriptive and normative" (Cohen, Manion and Morrison 2011, p.31), seeking not merely to describe or understand, but to move society and individuals further towards the goals of egalitarianism and social justice; its aim is not merely observation, but transformation (Delanty 2005, p. 71). This explicit recognition of the political nature of social research is understood epistemologically: "critical theory argues that in human affairs all 'facts' are socially constructed, humanly determined and interpreted, and hence subjected to change through human means" (Gibson 1986, p. 4). This understanding hints in turn at the intellectual lineage of critical theory, which includes connections to both the socialist perspective of Marxism and the psychoanalysis of Freud (Cohen, Manion and Morrison 2011, p. 32; Gibson 1986, pp.13-14).

Starting from this epistemological basis, the term 'critical theory' is currently used with a wide variety of meanings. Such a plurality follows in part inevitably from the recognition of the researcher as a meaningful component within the research process, as well as from the wide range of foci that this paradigm has been directed towards; it is therefore perhaps more accurate to talk of critical theor*ies*. Unfortunately, this diversity has contributed to some misunderstandings about what constitutes critical research, predominantly that "its emphasis is negative or carping... (and) somehow committed to fault-finding" (Smyth and Shacklock 1998, p.2). This claim however is essentially erroneous. Although critical theories do indeed attempt to "link explanation and criticism" (Gibson 2007, p.440), their fundamental commitment is not to censure, but to emancipate. Writing from within the field of mathematics education, Skovmose (1994) holds that:

"to be critical means to be directed towards a critical situation and to look for alternatives, perhaps revealed by the situation itself. It means to try to identify possible alternatives. Positivistic research looks for what is actual; critical theory looks for what is possible in light of what is actual and critical." (p.17)

This description is strongly consonant with the stated goals of this project, and begins to expound the purpose of locating this research within critical theory. Still, the quote above is only a partial staging of critical theory and it is important to recognise that, whilst censure is not the goal of critical research, there is an enhanced awareness of power relations and harms inherent in the societal status quo:

"Critical social research involves a perspective which sees social structure as an oppressive mechanism of one kind or another. This oppression is legitimated via dominant ideology." (Harvey 1990, p.32)

A critical epistemology thus not only allows but demands an explicit consideration of the political roles of mathematics education, whilst also urging exploration and analysis of their influence. This further supports the integration of a critical epistemology within this thesis. Adopting a critical stance does not ease either the complexity or the controversy of this task. Instead it demands a considered approach to a number of current debates, as well as a transparent and reflexive methodology designed to promote evidence over pure opinion, and to valorise reason over rhetoric. In this way critical theory is a proper, viable and potent choice of epistemology given the socially, historically and politically situated nature of the endeavour described in chapter one.

2.2 Critical Theory and Education

To illustrate further the value of critical purchase in educational research, this section will offer how critical theory has been deployed and developed, both within the study of education as a whole and mathematics education in particular. It will begin by looking at two key critical educational thinkers of the twentieth century, highlighting some preliminary concepts which will be drawn on in future chapters.

2.2.1 Bourdieu and Freire

Bourdieu was a French sociologist whose work encompassed a number of fields including education (Webb, Schirato and Danaher 2002). His work often centred on the power relations implicit in the structures and outworking of society; in particular he noted that education was a key mechanism in social and cultural reproduction (Bourdieu 1973). Bourdieu considered educational qualifications as cultural capital, awards which were authorised and recognised by society to carry an associated value. Bourdieu saw mathematics qualifications as a particularly potent example of this as discussed in section 1.2.1 (Bourdieu 1998). He also introduced the term 'symbolic violence' (Bourdieu and Passeron 1990) to describe the symbolic imposition of societally legitimised symbols and judgements in a manner which disadvantages certain social groups. Masculine domination is often given as an example of symbolic violence within contemporary society; within the discussion of this thesis the limitation of aspirations upon those who ultimately attain a D or an E grade at GCSE could likewise be construed as a form of symbolic violence, especially in cases where employment restrictions are less consequent from curriculum coverage than from an assumed standard or blanket judgement. This then is an example of how critical theory can be used to expose “oppression… legitimised via dominant ideology” (Harvey 1990, p.32), as discussed in the previous section.

Freire was a Brazilian educator whose academic writings focused on the topic of critical pedagogy. Rejecting the idea that education could ever be a politically neutral process, he held that both curriculum content and pedagogic approaches frequently served political agendas (Freire 1970). He was particularly critical of:

“the ‘banking’ concept of education, in which the scope of action allowed to the students extends only as far as receiving, filing, and storing deposits… in the last analysis, it is the people themselves who are filed away through the lack of creativity, transformation and knowledge in this (at best) misguided system ” (p.72).

Freire’s critique has a particular resonance with current debates in mathematics education that question widespread pedagogies arising from behaviourist psychologies, such as in the research of Harlen and Deakin Crick (2002) which illustrates how repeated summative testing can impact negatively on learners’ motivation and self-image. Through stressing distinction between the oppressors and the oppressed, Freire makes his readers more aware that many of the inherited practices of the classroom mirror oppressive society as whole, with the teacher dictating content, activity and behaviour, and confusing the authority of knowledge with the professional authority of their role (Freire 1970, p. 73). Freire’s writings have resonances with many of the ideas of Bourdieu, but they argue more strongly that the critical study of education involves the experiences of the individual as much as the decisions and judgements of societal bodies. In this way they offer critical purchase on not only the structure of education but its practices, not only its curricula but its classrooms as well.

2.2.2 Critical Theory and Mathematics Education

Mathematics is often considered to be a highly abstract subject, and as such it may be challenging in the first instance to conceive of mathematics education as ideologically loaded. Yet all education affects the life chances of its subjects, and so the politicisation of any area of education is inevitable (Carr and Kemmis 1986, p.39). Further, as was noted in chapter one, mathematics plays a dominant role within this conduct:

"Often with a psychological brutality that nothing can attenuate, the school institution lays down its final judgements and its verdicts, from which there is no appeal, ranking all students in a unique hierarchy of all forms of excellence, nowadays dominated by a single discipline, mathematics." (Bourdieu 1998, p.28)

This dominance insinuates the strong possibility of oppression; if any of the concerns which arise within a critical survey of mathematics education apply non-uniformly, some groups will be disadvantaged. Similarly, since mathematics education plays a role in preparing people to function in a democratic society, Mellin-Olsen (1987) argues that mathematics education becomes politicised as soon it aims to develop pupils' thinking. Therefore, wherever mathematical facility is being stunted through policy or practice, it is appropriate to follow Freire (1970) and support the use of the term 'oppression'.

Within mathematics education there exist much cited works which have revealed how specific groups were being disadvantaged by contemporary practices and provision within mathematics education. Walkerdine (1998) conducted both theoretical and empirical work demonstrating gender-based prejudices in the teaching and learning of mathematics. Likewise, Cooper and Dunne (1998) revealed surprising differences between the ways that children from different socioeconomic backgrounds interpreted items in national mathematics tests, and thus exposed a bias in the way that 'realistic' mathematics was being taught and assessed. There has also been considerable critical comment on contained biases of race and ethnicity in mathematics curricula; for instance Joseph (1987) challenges Eurocentrism in the way that the history of mathematics has been typically represented in schools. Each of these works has been built upon since and critical theory continues to be understood and explicated as a meaningful and valid basis for research in mathematics education (for instance Skovsmose and Borba 2004).

2.3 Relevant Ontological Debates

The research questions outlined in section 1.3 potentially invoke a number of significant ontological enquiries. Whilst reasons of space preclude a comprehensive examination of such issues, there follows a brief discussion about three key issues relevant to the synoptic aspects of this thesis, in order to support the methodology which follows.

2.3.1. Structure, Agency and Structuration

One relevant debate from within sociology is how best to conceptualise and research the interplay between organisations and individuals, between structure and agency. Shilling (1992) holds that since the 1970s much of the sociology of education can be considered as arising out of one of two schools of thought: structuralist accounts tend towards an emphasis on constraint and social structure, whilst interpretive accounts tend to stress the role of individual human agency. One of the most widely cited attempts to resolve this seeming dualism is Giddens' structuration theory, which holds that "social structures are both constituted by human agency, and yet at the same time are the very medium of this constitution" (Giddens 1976, p.121). This theory attempts to recognise the reflexive nature of social activity; social actors are aware of their position within society and are simultaneously restrained by and producers of (or *re*producers of) social structure. A useful analogy is that of syntax in linguistics (Parker 2000), since syntax both constrains and facilitates the production of meaningful strings of language. Whilst some sociologists (for instance Willmott 1999) hold that structuration fails to properly circumvent the need for some form of analytical dualism in practice, a rejection of a strict dichotomy between society and the individual can be usefully understood alongside a critical perspective as is outlined in section 2.2.

A related position is developed by Bourdieu across his works. Bourdieu's sociology is both objective and subjective; for Bourdieu "practice is always informed by a sense of agency… but… the possibilities of agency must be understood and contextualised in terms of its relation to the objective structures of culture" (Webb, Schirato and Danaher 2002, p.36). Cultural capital, for instance, can be gained to promote social mobility and increase an individual's agency, but access to cultural capital and its attendant value is determined by the external structures of society.

The coherence between critical approaches to sociology and an eschewal of extreme positions in this debate supports the adoption of the viewpoint within this thesis that structure and agency are ontologically interdependent and irreducible.

2.3.2 Identity and Figured Worlds

The ontological nature of identity is central to a number of contemporary debates within fields including philosophy, psychology and the social sciences. There has also been increasing interest of the role of identity and self-concept in educational progress and performance, for example in studies concerning the psychological construct of stereotype threat (Beilock, Rydell and McConnell 2007; Aronson, Lustina, Good. Keough, Steele and Brown 1999) and within research and writings about learners' concepts of their own intelligence and potential (Dweck 2000; Johnston-Wilder and Lee 2010).

Most current positions on identity challenge the essentialist position that identity is an individual core concept which is largely continuous and usually stable. Instead identity is conceptualised as something which acts as a medium for self-reflection and interpersonal interaction. Self is conjectured as a capacity rather than a quality; identity lies in practice, not repose (Holland et al. 1998, p.279), thus the sociologist Berger holds that identity is "socially bestowed, socially sustained and socially transformed" (1963, p.98). This position was notably espoused in the writings of the philosopher Foucault (for example Foucault 1977) who also argued the importance of discourse in shaping and expressing identity, and thus admitted the consequence of multiple identities arising from multiple discourses which are themselves linked to larger structures inherited from society. This understanding of how an individual's psychological construction of self relates to the wider social environment has resonance with the debate summarised in 2.3.1, since structuralism and post-structuralism both accentuate the place of language in the construction and evolution of personal identity (Gergen 1995).

The idea that identity is not wholly intrapsychic has been acknowledged within the field of educational research, notably in the work of Bruner (1996) who, in broad agreement with Foucaultian principles, holds that education is in fact crucial to the formation of self (p.35) and that "personhood implicates narrative" (p.40). Within mathematics education, work such as Boaler and Greeno (2000) and Black, Mendick and Solomon (2009) has explored the development of both identity and agency in the learning of mathematics. One notable question which has arisen out of this line of research is how dominant pedagogic practices impact on learner identities, asking in particular whether a presentation of mathematics as a discipline which apparently valorises the slavish application of rigid procedure and admits little independent thought or creativity could lead to rejection by pupils who are beginning to explore the limits of their own agency (see also Bibby 2009). This psychoanalytic approach has an interesting consonance with more traditionally interpretative research into student perspectives on pedagogy (for instance Nardi and Steward 2003).

One useful analytical tool of inquiry utilised by many of these researchers is the notion of a ‘figured world’. Holland et al. (1998) describe a figured world as:

“A socially and culturally constructed realm of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others. Each is a simplified world populated by a set of agents who engage in a limited range of meaningful acts or changes of state as moved by a specific set of forces.” (p.52)

A figured world is thus a simplified, often unconscious picture of a concept, practice or field, incorporating meaning, activity and what is ‘normal’. It is the figured worlds of the mathematics classroom which Boaler and Greeno (2000) criticise as being “unusually narrow and ritualistic, leading able students to reject the discipline at a sensitive stage of their identity development” (p.171). The concept of figured worlds plays an important part in analysing identity development, as it mediates between the influence of the macro-scale societal traditions, expectations and institutions and the micro-scale personal actions and interactions (Gee 2011, p.76).

The rejection of an essentialist notion of self in favour of a dialogic one has a number of immediate consequences for this thesis. Chief amongst these is that such a position foregrounds the relevance of learners’ conceptions of themselves as practitioners of mathematics, as “expertise, salience and identification codevelop in an interrelated process” (Holland et al. 1998, p.122). The learners’ ‘mathematical purpose’, as invoked in the second research question of section 1.3, is inevitably bound to the learners’ self-image as it pertains to mathematical activity, and to the learners’ figured worlds of mathematics. Second, this understanding of identity has methodological implications since data, particularly that arising from interviews, offers insight into the identity-shaping processes of the learners involved, and in some instances it is appropriate to employ the discourse itself as the unit of analysis. This will be discussed further in the individual methodology sections of the data chapters.

Finally, this thesis also draws on the concept of a ‘leading identity’ as introduced by Black et al. (2010). This term derives from Leont’ev’s (1981) notion of a leading activity, which is an activity considered to be dominant in shaping the psychic processes which support development; thus here a leading activity involves a shift in the learner’s motives to engage with mathematics. Correspondingly a ‘leading identity’ is a particular prevailing identity which reflects an underlying hierarchy of motives. This concept is highly relevant to the global research aims of this thesis, as it provides a conceptual framework within which learners might navigate tensions between the goals and roles of mathematics education by forming and reforming their mathematical identities around key practices and activities at different points in their mathematical histories.

2.3.3 Communities of Practice

The anthropological concept of a community of practice was introduced by Lave and Wenger (1991) and has since been extended and applied in a wide range of settings (for instance Wenger 1998; 2010). A community of practice comprises a group of people who share an interest, practice or profession. Newcomers to a community of practice partake in “legitimate peripheral participation”, introductory activity which is internally recognised as valid and meaningful, and which serves to introduce and induct an individual into the community. The concept of a community of practice speaks to both ontology and epistemology, since it not only describes a social structure but locates learning as a social practice:

“A person's intentions to learn are engaged and the meaning of learning is configured through the process of becoming a full participant in a sociocultural practice. This social process includes, indeed it subsumes, the learning of knowledgeable skills.”

(Lave and Wenger 1991, p.29)

A radical perspective on communities of practice thus holds that knowledge is situated and is indivisible from its social context. Although a full consideration of this position lies outside the scope of this thesis, it is noted here that situated cognition is broadly consistent with the tenets of critical theory.

The concepts of situated cognition and communities of practice have been successfully employed to research mathematical learning; in particular the much cited works of Nunes, Schliemann and Carraher (1993) and of Lave (1988) have shown that individuals use mathematics differently in different contexts. The constitution of a community of practice also fits neatly onto many contemporary environments of mathematical learning, such as undergraduate mathematics (for instance Solomon 2007a). The notion of communities of practice is further consistent with the previous discussion on identity and figured worlds, since membership in a community of practice both involves and influences knowledge, practice and identity. Wenger (2010, p.186) offers that:

"Identities become personalised reflections of the landscape of practices. Participation in social systems is not a context or an abstract, but the constitutive texture of an experience of the self."

This thesis therefore recognises and adopts the notion of a community of practice as a tool to research and foreground the context and social interactions involved in the processes of learning and identity construction.

2.4 Selecting a Critical Methodology

The discussions above have been offered to clarify the inferred meaning of the research questions and refine the critical approach of this thesis. Nevertheless, other dialogues, both informal and official, can make claim to critical purchase and thus it is finally necessary to choose and defend an appropriate methodology which can facilitate constructive and meaningful critical educational research. A first step in this process is to consider the suitability of approaches which have arisen out of a critical epistemology. Two of these will be presented here: action research and ideology critique.

Action research is a methodological approach which is, at present, often used by teachers to investigate and improve their own practice. It is a cyclical form of self-reflective enquiry which ostensibly links research to practice and frequently places the practitioner in the dual role of teacher-researcher (Carr and Kemmis 1986). Within each cycle a problem is identified, action is taken, observations are made and then self-critical reflection is undertaken. The reflexive aspect of action research, together with its stated goals of developing both one's environment and one's own facility to affect change demonstrates the close relationship between action research and critical theory; openly political or emancipatory action research in particular can be conceptualised as critical praxis (Cohen, Manion and Morrison 2011, p.349). Nonetheless, it should be noted that forms of action research can take place under other paradigms, and that recently links have been noted between the practice of action research and the tenets of the emerging paradigm of complexity theory (ibid., p.351).

My own personal history as a teacher and teacher educator establishes me as an actor within the field of mathematics education, and implicates action research as a prospective methodological approach. However, whilst the intention and underlying philosophy of action research fits well with the aims of this thesis, the scale and interest of the research questions go beyond what would normally be considered within an action research project. An appropriate methodology would of necessity have the potential to involve and consider a range of groups of learners in different situations. Further it would be challenging, if not impossible, to move meaningfully through more than one cycle of research on this scale within the time frame of a PhD; this constraint significantly disempowers an action research approach, and limits the potential for defending validity as it is understood within an action research context.

A wider-ranging methodology for educational research is the ideology critique offered by Habermas (1972). This consists of four stages: a description and interpretation of the existing situation; a presentation of the reasons behind the existing situation; an agenda for altering the situation; and finally an evaluation stage (Cohen, Manion and Morrison 2011, p.34). This approach articulates more closely with the research questions and scale of this thesis; indeed, it could be argued that chapter one is in some ways a form of the first of Habermas' stages. Nonetheless, this thesis stops short of being a full ideology critique, as it does not presume to possess either the authority or the latitude properly to promote any agenda for altering the researched situation in a conclusive sense. Instead it will attempt to navigate and interrogate a range of educational scenarios, so as to contribute to the second of Habermas' stages but not complete it. To this end this thesis will adopt a grounded theory approach as its overarching methodology.

2.4.1 Grounded Theory

Grounded theory is a widely used methodological approach which was first set out by Glaser and Strauss (1967), who espoused that "generating grounded theory is a way of arriving at theory suited to its supposed uses" (p.3). It differs from many other methodologies in that its first step is data collection, often from a variety of sources and through a variety of methods. The data is then analysed and compared to give rise to conceptual units, hierarchically termed codes, concepts and categories; these in turn support the proposal of hypotheses or generalised relations among the categories which can then be compared once more against the data.

"Abductive reasoning resides at the core of grounded theory logic: it links empirical observation with imaginative interpretation, but does so by seeking theoretical accountability through returning to the empirical world."

(Bryant and Charmaz 2007, p.46)

This process is termed 'constant comparison', wherein categories are constantly challenged and modified in light of new data until a point of theoretical saturation has been reached, and the extant coding supports an emergent theory. Thus "grounded theory can be presented either as well-codified set of propositions or in a running theoretical discussion, using conceptual categories and their properties" (Glaser and Strauss 1967, p.31). This thesis is herein presented as such a theoretical discussion.

Grounded theory is particularly well suited to the overall research questions of this thesis as it befits the exploration of multiple groups of learners, excels at drawing comparisons between multiple sets of data, and offers a logic for qualitative research which supports the inclusion of narrative and discourse-led data. The research questions offered in section 1.3 support such an approach; the competing goals and roles of mathematics education undoubtedly influence different groups of learners in a variety of ways, but any wider critique of ideology is arguably dependent on a facility to recognise and reflect on commonalities within these different outcomes. Whilst different methodological tools and approaches will be chosen to fit the existing situation of each individual group of learners, the continuing, synoptic analysis will be undertaken using a grounded theory approach.

The specifics of the application of grounded theory to this thesis are outlined in section 2.5 below, but as grounded theory is not a specifically critical methodology it is necessary first to clarify the nature and qualities of a critical grounded theory.

2.4.2 Critical Grounded Theory

There is no single answer to the question of whether the methodology of grounded theory is compatible with the epistemological position of critical theory. As noted in section 2.1, it is more accurate to speak of critical theor*ies*, and there further exists a range of approaches to grounded theory; Glaser and Strauss, the two original proponents of grounded theory, have their own methodological schools of thought, and further blends of grounded theory have evolved over time (Bryant and Charmaz 2007). To illustrate the potential for both synthesis and conflict between grounded theory and critical theory, this section will consider (after Gibson 2007; Karakayali 2004) how grounded theory might be judged using the ideas of two key critical theorists: Adorno and Bourdieu.

Adorno was a German critical theorist of the twentieth century who considered that:

"sociology was as much a product of society as capital, labor or domination… (hence) in Adorno's perspective, grounded theory, because it did not go beyond the immediate appearances of society, would be nothing more than a bourgeois sociology reinforcing the domination inherent in society"

(Gibson 2007, p.438)

This is an extreme position, but one which demands recognition, if only as a reminder that by starting with data and anticipating that patterns will 'emerge' (whereas a critical epistemology would more likely hold that relationships are inferred by a social actor) grounded theory approaches risk reproducing or reacting to various social biases and power relations. Multiple ideological concerns arise out of Adorno's perspective: there is not only scope for grounded theory to be used to support the presentation of imitated and subjective reasoning as being in some sense objective, but also a danger that the processes of grounded theory might further objectify researched participants. Whilst this thesis does not fully assume the position of Adorno, measures taken to assuage such concerns are included throughout this thesis, chiefly in the sections discussing ethics, validity and reliability.

For other critical theorists such as Bourdieu, the practice of sociology also begins with sociologists themselves, since "sociologists, just like anyone else, have internalized a spontaneous knowledge of the everyday world" (ibid., p.439). In contrast to Adorno, however, Bourdieu would argue that this does not refute the value of individual sociological thought, but necessitates sociologists maintaining a continuous self-awareness; in short, Bourdieu advocates a reflexive sociology, and this can be extended to include grounded theory approaches. In the context of this thesis, a Bourdieusian stance would insist on the inclusion of an explicit recognition of my own experiences and mathematical trajectory, and of how my personal perspective on the philosophy of mathematics education might steer both my unconscious and conscious choice of codes, concepts and categories. This is the position adopted herein and hence the three data chapters will each contain a short précis considering the researcher as a research instrument.

The discussion of Adorno and Bourdieu demonstrates that tension between a critical position on the nature of knowledge and a grounded theory approach to constructing it is unavoidable but not prohibitive; indeed, it could be argued that the overtness of this tension usefully foregrounds issues which are relevant to all critical sociology. The central issue is one of balance: a preoccupation with the emancipatory intentions of critical theory could lead to forcing (Glaser 1992) and a move away from concepts arising more authentically from the data; conversely, whilst reflexive practice is an integral part of the critical theory stance adopted here, a fixation with reflexivity could move the focus away from the intended target of the research. Nevertheless, a measured sensitivity to the influence of extant ideology, as well to one’s own experiences and figured worlds, allows for grounded theory to be performed meaningfully and productively from a critical standpoint (Gibson 2007).

2.5 The Overarching Methodology

The research questions constructed in chapter one were:

- How do the experiences and mathematical trajectories of learners reflect the competing goals and roles of mathematics education?

- How do learners navigate and make sense of competing or co-existing goals and roles of mathematics education? In particular, how do they make sense of their own mathematical purpose?

The discussions above have explicated much of the theoretical framework assumed behind these questions, and defended the choice of a critical grounded theory approach. The remaining part of this chapter will outline the overall methodology used in this research.

2.5.1 Theoretical Sampling

Any attempt to address the research questions above must of necessity consider a range of learners, as a narrow focus would not differentiate sufficiently between issues specific to a group of learners and phenomena and relationships with a wider significance. The research was therefore conducted in an episodic manner, with each research project focusing on a different group of learners. Four contrasting and complementary groups of learners were chosen to include a range of ages and attainment levels and also to support the later claim of theoretical saturation. Each group was theoretically identified prior to sampling as lying at the intersection of multiple goals and roles of mathematics education. The term 'intersection' is used henceforward as a shorthand to express both that multiple purposes of mathematics education were directly significant to these learners at the time of the research, and that these learners had been exposed in some form to the various discourses associated with these purposes.

The first group of learners considered was adults who had previously left formal schooling and had returned to the study of mathematics after a time away. These learners were identified as being distinctive since they had made a choice to return to a subject that they had previously left behind; this contrasts starkly with the high levels of disaffection that have been reported in secondary mathematics (for instance Nardi and Steward 2003; Smith 2004) and suggests that new goals and roles of mathematics may have become apparent to these learners since leaving school, influencing their decisions. This section of the research project is presented in chapter three.

The second group of learners sampled were undergraduates at a respected English university who were about to complete a degree in mathematics, but who had openly decided to move away from mathematics after graduating. These learners could be conceptualised as lying very definitively at the intersection of various goals and roles; whilst their mathematics degree remained a valuable piece of cultural capital, their decision not to go into mathematically-based employment or further study suggests that their perceptions of mathematics had changed since embarking on their mathematics degrees. This change of direction also contrasts neatly with that observed in the first group of learners. This section of the research project is presented in chapter four.

The final two groups of learners were secondary school students working towards their GCSE qualification in mathematics. The third group consisted of students who had been identified by their teachers as being on the C/D grade ‘borderline’; this group was therefore at risk of being particularly exposed to the prevailing discourse that a C grade in mathematics is crucial for advancing life chances. This group was sampled across a cross-section of schools to further explore how students recognised and responded to different presentations of the purpose of mathematical study and the associated C grade. The fourth group consisted of students in the same schools who were working towards F and G grades at GCSE; the intention here was to examine how these learners made sense of their mathematical purpose given that they were not working towards the level of qualification advocated as essential for their peers. The research project which involves both of these groups of learners is presented in chapter five.

Whilst the four groups of learners are diverse enough to report a rich range of experiences and perspectives, together they offer useful coverage of a number of demographic and theoretical dimensions. In terms of age, the learners in groups three and four are still at school, the learners in group two are taking part in undergraduate study and the learners in group one are in adult education. In terms of attainment, the learners in group two represent high attaining students, the learners in group three are close to a median level of attainment and the learners in group four are low attaining; the adult learners of group one further bolster these last two categories. Similarly, these groups encompass a range of stages of mathematical study.

The exact compositions of the samples and the roles of practical, ethical and time constraints are provided in the respective chapters which follow.

2.5.2 Tailored Approaches and Constant Comparative Analysis

Within each project the overarching research questions were interpreted in terms of the research subjects and their particular context, and then operationalised. For instance, in the case of the adult returners of group one, the mathematical trajectories hinged on the decision to return to mathematics, and so the localised research questions focused in part on the reasons behind this decision. Conversely, the trajectories of the undergraduates in group two involved a number of critical junctures, including one decision to undertake a mathematics degree and another decision to leave mathematics behind. This necessitated re-construed research questions and the use of a corresponding methodology within the critical grounded theory outlined above which encompassed more fully and more validly the trajectories of the participants.

Despite this diversity of approach, each group contributed in turn to the development of an emerging grounded theory. In line with the constant comparison method, data was continually coded and connections were made between the experiences and opinions of participants of different groups (see figure 2.1 overleaf). A simplified report of the development of these codes is presented alongside the data in the following chapters.

It should be recognised at this point that each of the research projects was also presented in a discrete form. The data from group one was presented at a researchers' conference (Ward-Penny 2009) and written up as an MA dissertation, where the MA formed part of a 1+3 programme agreed as a condition of the sponsorship of this PhD. The research surrounding group two was developed as a standalone paper (Ward-Penny, Johnston-Wilder and Lee 2011) and the research from groups one, three and four was presented to interested participating centres in line with the democratising ethos of critical grounded theory. This approach guaranteed a thorough examination of the data at each stage before moving on, so that whilst categories were not rigidly defined at intermediate stages, the data was sufficiently analysed so as to inform future sampling and research design.

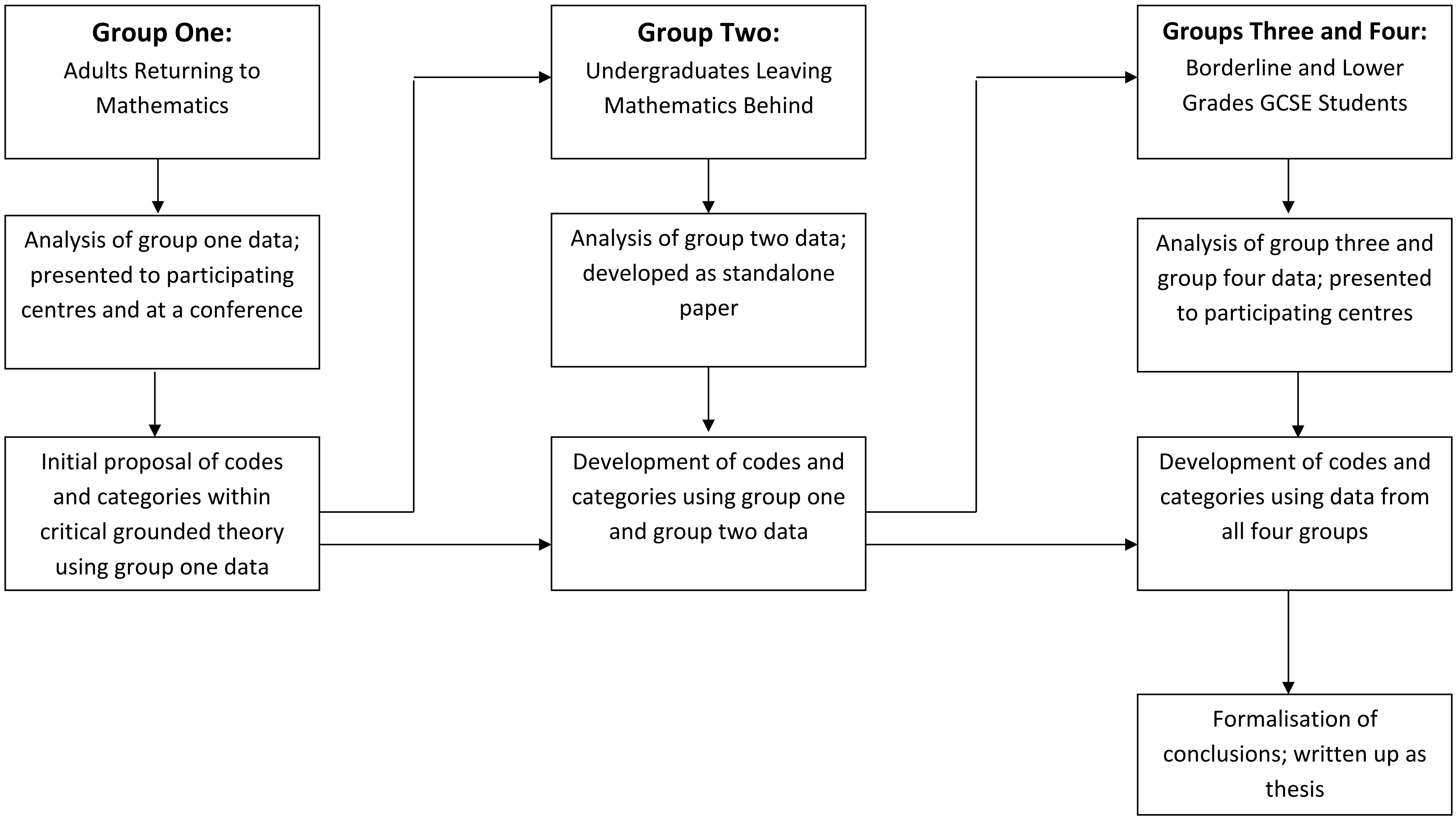


Figure 2.1 Summary Structure of the Research

2.5.3 Validity and Reliability

As validity and reliability concerns are all contingent on methodological choices and practices, these interests will be addressed more fully and directly in context within each of the following data chapters. However, it is appropriate briefly to consider here the meaning of these two terms within a critical grounded theory approach.

The notions of validity and reliability in a critical theory context can be questioned at a fundamental level (for instance Cohen, Manion and Morrison 2011, pp.34-35). As critical theory research cannot fall back on the verification processes and naturalistic ontology of positivism, it can be considered to be at risk of prompting a tautological corroboration process whereby valid critical theory is considered that which is approved by recognised critical theorists. Equally, the range of critical theories available risks the introduction of researcher bias when establishing the field of investigation; as an extreme example the integration herein of relevant ideas of Adorno and Bourdieu but not those of Marcuse (for details see Gibson 1986, pp.32-33) might be evaluated as being not only selective, but invalidly subjective. These are valid concerns which stem from the epistemological basis of critical research and cannot be entirely dismissed.

Notwithstanding concerns such as those offered above, it is possible to continue to lay claim to the notions of validity and reliability from within the critical theory canon. In the first instance, adopting a critical stance does not negate the value of standard measures taken to support claims of internal validity; in this way the following chapters include many uses of quantitative tools such as Cronbach's alpha and factor analysis (sections 3.3.2 and 5.2.5) as well as qualitative tools such as the use of multiple interviewers and transcript checking (section 4.3.4). In addition to this, critical theory demands some evaluation of the emancipatory and empowering potential of the research as whole; this is sometimes termed catalytic validity, “the degree to which research moves those it studies to understand the world and the way it is shaped in order for them to transform it” (Kincheloe 1995, pp.81-82). This is a challenging mandate and one which is somewhat frustrated by the nature and timescale of this thesis; the majority of the hoped-for impact of this research as a complete body of work unavoidably lies in the future. Therefore the final chapter will explore and uphold the potential catalytic validity of this work. In this way it is intended that the claims to validity and reliability for this research will be further established jointly through the retention of established methodological practices and a continual, critical consideration of the resultant potential for emancipation and amelioration.

CHAPTER THREE: EXPLORING THE DECISIONS AND EXPERIENCES OF ADULTS RETURNING TO MATHEMATICS

3.0 Introduction

The discussion in chapter two argued that in order usefully to explore co-operation and competition between the purposes of mathematics education it was necessary to consider learners who were clearly functioning at the intersection of multiple goals and roles. Whilst all contemporary learners are exposed to multiple discourses surrounding mathematics education, the tensions between the purposes of learning mathematics are arguably rarely as recognisable as they are amongst subgroups of learners who act in an unusual way, or decisively change the course of their mathematical trajectories (Noyes 2007). To this end, this first data chapter takes as its subject one group of learners which qualifies on both of these counts: adults who choose to return to the formal study of mathematics, having previously left the subject behind.

My own experience of meeting such individuals before beginning this study had alerted me to significant diversity within this group. I had met amongst others: an actress in her twenties who wanted to upgrade her E grade at GCSE to help her get temporary jobs; a secondary school teaching assistant in her forties who wanted to feel more confident when helping pupils in class; and a music teacher in her fifties taking AS-level mathematics as she felt she had missed out on something at school and wanted to help her teenage children with their own mathematical education. Even though their backgrounds, motives and levels of study were diverse, each of these individuals had acted against the trends of disaffection and under-participation delineated in chapter one, and so could be argued to be representative of a wider cohort, or possibly cohorts, apposite for analysis.

In order to foreground the apparent volte-face of such learners, so as to concentrate better on the competing goals and roles of mathematics education in England, this exploratory research considered the decisions and experiences exclusively of learners who had returned to the study of mathematics, at whatever level and for whatever reasons, after a definite, identifiable period of time away from the formal study of mathematics in the English school system. This definition has been précised elsewhere (Ward-Penny 2009) through the use of the epithet 'prodigals' after the biblical parable, and this term will also be used herein as a shorthand. Whilst other groups of adult learners are undoubtedly relevant to the wider discussion of this thesis, this delineation was considered both necessary and valuable in order to support stricter comparisons, as well as to promote more meaningful summaries of the data and more direct illumination of the research questions. For instance, adult learners who had decided to formally study mathematics after attending school in another country and moving to England would have been exposed to multiple arrays of educational philosophies, and associated cultural shifts may have complicated or even directed how they saw their own mathematical purpose. Equally, learners who had continued their study of mathematics without an interval by moving directly from school to further education were excluded in order to maintain an emphasis on individuals who had deliberately and purposefully altered their own mathematical trajectories. Conversely, this restriction presumed neither a uniform model of provision or curriculum, nor did it preclude the inclusion of adults studying towards different levels of qualification. This classification is developed into a full sampling frame below in section 3.3.1.

3.0.1 Localising the Research Questions

In order to operationalise this stage of the research it was first necessary to consider what particular perspectives and insights these learners might shed on the global research questions. These questions were first stated in section 1.3 as follows:

- How do the experiences and mathematical trajectories of learners reflect the competing goals and roles of mathematics education?
- How do learners navigate and make sense of competing or co-existing goals and roles of mathematics education? In particular, how do they make sense of their own mathematical purpose?

The common incident central to this group, and that which arguably has the potential to reflect most clearly the competing goals and roles of mathematics education, is each prodigal’s decision to return to mathematics. A close association between the purposes of mathematics education and the prodigals’ decisions is both consonant with, and theoretically plausible within, different schools of thinking regarding decision making (for instance, Hastie and Dawes 2010). In psychological models which conceptualise decisions as responses to personally constructed sets of needs and preferences, the goals and roles of mathematics education can be understood as contributing to this construction, such as in the case of the teaching assistant who took GCSE mathematics as she wanted to feel more confident when supporting pupils in class. In cognitive models where decision making is a process that responds to external or environmental stimuli, the goals and roles of mathematics education could be thought of as contributing either directly or indirectly to these stimuli. Similarly, in normative models of decision making such as mathematical game theory where decisions are seen as logical choices designed to maximise some form of profit or advantage, the goals and roles could be seen as qualifying or even quantifying different outcomes and achievements as things of worth. In these ways, the actress who returned to education to improve her GCSE mathematics grade might be construed as either responding to the stimuli of the demands of the job market (demands which are closely associated with some of the goals and roles outlined in chapter one,) or acting to maximise her cultural capital by obtaining a key mathematical qualification.

The centrality of the decision making process thus gave rise to three localised research questions, of which the first two are:

- **Who are the prodigals?**
- **What motivates the prodigals to return to learning mathematics; in particular, what roles or goals are at play in these decisions?**

The second of these questions is a focused wording designed to facilitate exploration into both the prodigals' mathematical trajectories and their sense-making processes, so as to elucidate the global research concerns. The introductory and complementary first question is then necessary to offer context and clarify the data so that its messages are more fully understood. As well as reporting on demographic characteristics such as age and gender, this question involves the prodigals' educational biographies and thus offers important context; it would be difficult to infer or discuss confidently the place and relevant impact of a mathematics qualification for an individual without considering first their prior qualifications.

Whilst the decision to return to mathematics is fundamental in exploring the influence of the goals and roles of mathematics education on the prodigals, this group offers opportunity beyond simply considering the decision itself; having experienced mathematics education in two contrasting environments, and in two institutions which are likely to respond differently to the varied purposes of mathematics education, these learners can offer a useful perspective on the similarities and differences which they have observed:

- **How do the prodigals' experiences of learning mathematics as an adult compare to, and contrast with, their experiences of learning mathematics at school? What changes are there in the ways that the goals and roles of mathematics education are navigated or made sense of by these learners?**

The intention here was that establishing a direct comparison between the two sets of experiences would highlight differences that can then in turn be understood as resulting, at least in part, from a shift in the balance of the contending goals and roles outlined in chapter one. For instance, it might be expected that the goal of inculcating a sense of numeracy might be differently emphasised in adult education institutions as compared to school, since the majority of adult learners are likely to have a wider body of experiences to draw on; similarly the prevalence and presentation of this particular goal might vary between an adult numeracy course and a course for adults which culminates in the GCSE mathematics examination.

In this way these three localised research questions offered meaningful explication of the global research questions of this thesis, and could be in turn operationalised into a localised methodology which is described below in section 3.3. The findings of this research are presented in sections 3.4 and 3.5; the contributions of these results to the global research questions are then discussed in section 3.6.

3.1 Literature Review

This section summarises the parts of the overall literature review which support this particular component of the thesis research, namely those concerned with adult numeracy, adult learners of mathematics and the perception of mathematics as a gatekeeper for adult employment.

The review was originally conducted in 2008 in the following manner. The review began with a selection of books and journal articles, found by submitting variations of the key terms ‘adult learners’, ‘mathematics’ and ‘numeracy’ into the electronic database of books run by the University of Warwick library and the Educational Resources Information Center (www.eric.ed.gov). A manageable initial core of items was then chosen on the basis of relevance and how recently they had been published; at this stage no items which were more than 15 years old were included. The literature review was then expanded to include:

- articles or books referenced by one or more of the initial texts that seemed highly relevant to the research questions and/or significant in the field;

- reports and research summaries by national organisations concerned with adult numeracy (particularly the National Research and Development Council and the Basic Skills Agency);

- a small number of widely cited pieces of research concerning motivation in the learning of mathematics without a specific focus on adult learners.

A sufficient degree of saturation was assumed when all included specialist terms and theoretical concepts were understood, and the readings seen as most central to the research questions were considered to form a coherent whole with no major works missing.

The literature review was revisited in mid-2012 during the final writing up of this thesis, using ERIC systematically with the same key terms to select and locate relevant publications dated between 2008 and 2012.

3.1.1 Adults Learning Mathematics: Participation, Profiles and Politics

It is difficult to discuss succinctly the demographic profile of adults learning mathematics without compromising on either accuracy or meaning. This is partly because the sector is broad, encompassing casual attendees of a basic numeracy course, distance-learning students who might be excelling at degree level study and many others between. Even within one level of study there is much variation; Coben (2003) notes that "experience tells anyone who has ever worked with adults that there is no such thing as a generic adult learner of numeracy" (p.73). Further, "the whole concept of participation in such a large, diverse and complex sector is highly problematic" (Benn 1997, p.16). Adult learners are frequently part-time, often attending courses in a flexible way due to other demands on their lives (Hamilton and Hillier 2006, p.51); many are known to drop in and out of formal provision, responding to pressures in such a way that belies an equation of persistence in learning with course completion (Crowther, MacLachlan and Tett 2010, pp.651-2; Carpentieri 2008a, p.20).

The historical and political nature of some of the issues surrounding adult learners might also contribute to a distorted picture of participation. ‘Basic skills’ courses, including numeracy courses, became much more numerous, available and recognised in the 1990s, leading Benn (1997) to claim that “returning to study is seen by more adults as natural, almost inevitable” (p.47). However, this rapid growth in provision and the new initiatives that took place under the ‘New Labour’ government (Hamilton and Hillier 2006) may have skewed some statistics of participation and certainly some measurements of success. There is also no uniform definition about what constitutes numeracy, as discussed above in section 1.1.1. Coben, in her review of numeracy-related research (2003), described the field of numeracy as “fast-developing, but under-researched, under-theorised and under-developed. It is a deeply contested concept which may be best considered as mathematical activity situated in its cultural and historical context.” (p.7) Similar levels of uncertainty are expressed by Hamilton and Hillier (2006) who claim that “there is more speculation and opinion about *(adult learners)…* than there are hard facts and figures” (pp.43-44). Whilst more recent research such as Coben et al. (2007) and an increasing number of longitudinal studies (Reder and Bynner 2009) have begun to address gaps in the research, our understanding of adult learners is still incomplete and reported results are subject to political interpretation as well as academic criticism. Recognition of these tensions does however support the conceptualisation of adult learners of mathematics as existing at the intersection of multiple goals and roles of mathematics education.

The available data on adult learners of mathematics is thus partial and problematic: “we have too little *(data)* and… what we have is distributed in a fairly arbitrary fashion across issues and topics” (Coben 2003, p.110). Yet whilst it is difficult to draw out definitive demographic summaries, some data does exist concerning subgroups of adult learners within specific pieces of research, and this allows for some preliminary comparisons. For instance, Benn and Burton (1994) reported the demographic breakdown of a sample of learners (n=1471) on Access to Higher Education or ‘Access’ courses, and this is given below in tables 3.1a and 3.1b. ‘Access’ courses, which contain a mathematics requirement, are designed for adult returners who want to move on to higher education but lack the necessary qualifications.

Gender	**Percentage**
Male	30.2
Female	68.1

Age Group	**Percentage**
18-21	7.9
22-30	41.1
31-40	36.6
41-50	10.7
50+	2.4

Tables 3.1a and 3.1b: Gender and Age of Learners on ‘Access’ courses in Research Sample (n=1471), Benn and Burton (1994)

These figures are markedly similar to the reported proportions for current 'Access' courses (QAA 2011) and thus appear to be loosely indicative of this subgroup. In a related paper (Benn and Burton 1993) the authors examine the previous educational history of their sample: 35% had no mathematics qualification upon joining the course, and a further 49% had a mathematics qualification that was no higher than a GCSE Grade D or equivalent (p.184).

More recent data on numeracy course participants is offered by Coben et al. (2007, p.16) and is reproduced below in tables 3.2a and 3.2b.

Gender	Percentage
Male	46.1
Female	53.9

Age Group	Percentage
16-19	40.5
20-29	19.9
30-39	18.7
40-49	12.1
50-59	4.9
Over 59	2.2

Tables 3.2a and 3.2b: Gender and Age of Learners on Adult Numeracy Courses, Research Sample (n=412), Coben et al. (2007)

The gender bias present in the 'Access' learners is still present but less pronounced; nonetheless, it is still a common finding in numeracy research, with Carpentieri (2008b) summarising that "women were better represented in numeracy courses than men" (p.3). It is also noteworthy that the numeracy learners also exhibit a stronger positive skew with respect to age than the ‘Access’ learners.

Notwithstanding these findings, it is entirely possible that age and gender are not the most relevant features which might be utilised in constructing a better awareness of adult numeracy learners. The International Seminar on Adult Numeracy (CUFCO 1993, cited in Benn 1997, p.18) found that despite wide demographic differences between cohorts of numeracy learners in different countries, there was significant commonality in their social backgrounds. Most belonged to the ‘fringe of society’ and possessed a limited cultural fund. Whilst the authors at the time recognised that “this may in part be due to methodological differences in data collection… *(it)* may also reflect the particular position of mathematics as a gateway subject” (ibid., p.18). In this way, in order to understand more fully who the prodigals are and frame them against the global aims of this research, it is necessary to consider how the goals and roles of mathematics education might be understood by adult learners of mathematics.

3.1.2 Mathematics as a Gatekeeper: Evidence of the Goals and Roles of Adult Mathematics in the Research Literature

Section 1.2 has already argued for both the place and strength of mathematics qualifications as cultural capital (after Bourdieu 1973) in contemporary society. Numeracy commands a particular potency within this, since “numeracy skills affect life chances and ambitions, from childhood into adulthood” (Carpentieri 2008b, p.3). This claim is borne out empirically: “at the age of 30 men and women with poor numeracy were more than twice as likely to be unemployed as those with competent numeracy, and men with poor numeracy had the lowest rates of pay” (ibid., p.2). Facility with basic skills (including numeracy) has been shown to predict youth unemployment internationally (Lundetræ, Gabrielsen and Mykleten 2010). Reports such as Parsons and Bynner (2006) seem to suggest further that poor numeracy has a greater impact than poor literacy on an individual’s prospects, and also that poor numeracy is more disadvantageous to women than to men. It is in this vein that Hamiliton and Hillier (2006) opine that numeracy (and literacy) has a “strong symbolic value” within our society linked to its “practical role in conferring status, opening access to new opportunities, its gatekeeping role and use as a common yardstick to judge people’s general competence and how cultured they are” (p.48). Noyes (2007) similarly holds that mathematics is the subject “most likely to hinder progression towards further and higher education and employment opportunities” (p.4).

There exists a range of situations in both employment and education where mathematics acts as a gatekeeper. For instance: initial teacher training courses require candidates to both demonstrate competence at GCSE Grade ‘C’ or equivalent and pass an additional timed numeracy test (DfE 2013); nursing students are required to achieve full marks in a ‘numeracy in practice’ test before registering on a training course (NMC 2010; Coben and Hodgen 2008); and many learners taking part in the ‘Access to Higher Education’ route discussed in 3.1.1 are required to pass a GCSE-equivalent qualification in order to pass their overall diploma (QAA 2008). Many prodigals are likely therefore to be guided towards the study of mathematics as part of one such route. Research such as Benn and Burton’s study of ‘Access’ students (1993) suggests that the consequences of such compulsory integrated content can vary considerably, with some learners seeing mathematics as an insurmountable barrier that precludes them and others being enabled and overcoming negative school experiences.

The substantive position of mathematics as a gatekeeper to education and employment shows that, in the terms of chapter one of this thesis, adults learning mathematics are quite explicitly exposed to some of the political and social roles of mathematics education. In her discussion of adult mathematics education in the U.S., Kantner (2008) notes that these are often held in tension: "mathematics has conflicting roles in adult education. On an individual level, a lack of mathematics can be a source of disempowerment for adults. Mathematics becomes an academic skill gatekeeper to adult employability… on a societal level, mathematics can be a means for dominant cultures to marginalize subgroups within societies… Mathematics and social stratification interact" (p.6). This comment is strongly consonant with Bourdieusian ideas of social and cultural reproduction, but it is important to stress here that a fuller critical perspective would also question the simplistic assumption that adult learning of mathematics fully develops learners' cultural funds and redresses imbalances. The normative assumptions implicit in the term 'basic skills' for instance could be argued to actually disempower learners in some sense; Oughton (2007), in performing a critical discourse analysis of the Adult Numeracy Core Curriculum, posits that through participation learners are construed as 'deficient' and excluded from what might be considered to be high-status academic mathematics. This line of analysis could support an argument that the roles of mathematics as a politically selected gatekeeper subject and as a contributor to social reproduction are sometimes in tension.

It is not only the roles that are held in balance, but also the goals. Hillier (2009) highlights two dominant discourses in Adult Literacy, Language and Numeracy (ALLN) education: a functional, technicist approach which conceives of 'basic skills' as being procedure-based, and the beginning of a larger, hierarchical mathematics curriculum; and a social practices approach which understands 'basic skills' as being individual, and determined by the nature and content of a learner's personal and professional lives. These two approaches resonate differently with the set of goals isolated in chapter one, with the focus alternately on mathematics that is deemed useful by industry or society, and mathematics which is chosen as useful by the individual.

3.1.3 The Decision to Return to Mathematics

At the time of writing there is a paucity of research which directly examines the specific reasons that motivate learners to return to mathematics. The notable exception is Coben et al. (2007) which offers the six most popular reasons selected by learners on a numeracy course. These are reproduced overleaf in table 3.3.

Despite the relevance of this data, it should be noted that this sample only comprised of learners on numeracy courses, and further that over 40% of the group was aged between 16 and 19, and thus may have arrived on the course directly from school, contrary to the definition of prodigal. Coben et al. comment that reasons to attend numeracy classes are "many, intricate and overlapping", but do offer some trends; the 16-19 year olds were much more likely to view attendance instrumentally, as an obligatory part of training or a wider course of education, whilst older learners were more likely to refer to personal or intrinsic motivations. Notably, the motive of preparing oneself to help one's children was almost exclusively reported by women (p.20).

Reason For Doing Course	**Percentage of Overall Sample**
To get a qualification	57.5
To get a better job	42.5
To prove something to myself	37.4
To help me become more confident	37.1
To help children with homework	20.1
To help with everyday things outside the classroom	20.4

Table 3.3: Reasons for Doing a Numeracy Course (n=412), Coben et al. (2007, p.19)

The decision to return to formal study is characterised in the extant literature as being both gradual and sudden. Hamilton and Hillier (2006) model the process as first consisting of growing concerns, such as barriers at work, a sense of having 'missed out' at school, or concerns about children's schooling and development; each learner's decision is then "triggered suddenly by events in their lives which make them reassess" (p.48). This process has been deconstructed further by writers such as Mezirow (1981) who delineates ten phases that constitute 'perspective transformation' (p.7). However, whilst Mezirow sees adult learning as potentially emancipatory, and his stages sit well with a critical theory of numeracy education, this level of specificity is perhaps unhelpful outside of a more detailed, longitudinal study than is intended here. Conversely, it is useful to note that the notion of cultural capital has explanatory power once more. Since mathematics is deeply integrated into the cultural capital of contemporary British society, any individual who is not numerate is likely to become increasingly aware of this deficit as they gather cultural capital over time; it is hard to select the optimum mortgage, budget for a family or progress into managerial or supervisory roles without some grasp of the relevant mathematics. Thus the acquisition of other cultural capital might itself lead to the trigger described by Hamilton and Hillier and force a decision to return to mathematics.

Researchers' understanding of the decision to return to learning mathematics is also informed by the actions of those who do not make a successful return to learning mathematics. First, current summaries of provision (for instance NIACE 2011) are increasingly aware that the majority of adults who have poor numeracy do not return to formal mathematics education; NAO (2008) reports that only one in ten adults with numeracy "below functional level" have attended a numeracy course (p.10). Second, many who do attend a course drop out before completion. Drop out is a significant phenomenon in the adult education sector, although the complex patterns of attendance described in 3.1.1 make it a difficult one to explore. McGivney (2003) summarises the available research and institutional data and awards great significance to personal and social reasons. A continuation of this reasoning suggests that the decision to return is more likely to be taken when personal and social factors are conducive; for example since "combining domestic responsibilities with study is a common problem for women students" (p.105), some mothers might wait until their children have reached school-age before deciding to apply for entrance onto a mathematics course.

Although adult learners' decisions to return to the formal study of mathematics are only broadly understood, some useful theoretical support can be gathered by grounding the decision in the wider literature concerning learners' motivation in mathematical learning. This literature also provides some context for the discussion of differences observed by the prodigals between learning at school and in an adult education environment.

3.1.4 Adult Learners and Motivation

Motivation in education is a complex issue which has given rise to a significant range of theoretical orientations. Middleton and Spanias (1999) identify five areas of common understanding across the literature:

- students' perceptions of success in mathematics are highly influential in forming their motivational attitudes
- motivations towards mathematics are developed early, are highly stable over time, and are influenced greatly by teacher actions and attitudes
- providing opportunities for students to develop intrinsic motivation in mathematics is generally superior to providing extrinsic incentives for achievement
- inequities exist in the ways in which some groups of students in mathematics classes have been taught to view mathematics
- achievement motivation in mathematics… can be affected through careful instructional design

(pp. 79-82)

It is indicative of the import of motivation to adult learning that these findings can be connected with salient characteristics of the adult learning experience.

Research and guidance about adult education have long stressed the learner-centred nature of learning experiences, with learners contributing to the content and presentation of lessons; for instance, Brookfield (1986) holds that effective group practice "involves a continual renegotiation of activities and priorities" (p.10). In their critical history of basic skills provision Hamilton and Hillier (2006) comment on the same learner-centred principle, linking it both historically and ideologically with one-to-one tuition and remedial schooling. Benn (1997) similarly identifies the centrality of the individual as "the one feature which is consistently held up as the identifying characteristic of adult education" (p.10) and the adult capacity for self-direction forms the basis of distinct theories of adult learning such as andragogy (Knowles 1973). Foregrounding adult learners as individuals allows for the inculcation of intrinsic motivation, as well as affecting achievement motivation through instructional design.

Teacher actions and attitudes have also been observed to be notably different in adult education classrooms, again in line with Middleton and Spanias' findings. Hallam (2005) sees the adult educator as a nurturer who develops over time into a high-status role model for the learner; she also connects this nurturing position with the ideas of Dweck (2000), proposing that the actions and attitudes of teachers are instrumental in developing learners' personal theories of intelligence. Differences in how learners consider their own potential undoubtedly colour their personal views of mathematics, and what constitutes success in the subject (Lee 2009).

Middleton and Spanias' findings also have connections to pedagogical matters which concern all learners of mathematics. For instance the conclusion that developing intrinsic motivation is ‘generally superior’ to providing extrinsic incentives is supported by Harlen and Deakin Crick (2002) who demonstrated that summative tests reinforce tendencies to associate self-esteem with achievement and valorise performance over learning goals. Equally, the import and motivating value of ‘real-life’ questions in mathematics has been noted in writings centered on both adult mathematics education (for instance Evans 2000; Benn 1997) and school mathematics education (for instance Ward-Penny 2010). Hallam’s exhortation that educators offer “interesting, challenging work, set at an appropriate level which is perceived to be relevant to personal learning goals” (2005, p.26) is also relevant for teachers of any age group.

Adult learners, then, are motivated to learn in much the same way as any learners, although any conceptualisation of adult motivation must recognise the different range of pressures and demands that typically affect adults and their choice of ‘goal states’ (Smith and Spurling 2001). It must also be recognised that adults are more likely to be at risk of possessing ‘baggage’ which affects their self-concept and self-confidence; this could range from negative associations to cases of mathematics anxiety (Ashcraft and Ridley 2005). It has even been suggested (Carpentieri 2008b, p.2) that the commonness of negative associations with mathematics could help to explain why course participation rates are typically lower for numeracy than for literacy. In conclusion though, it is important to recognise that motivations are as individual as the learners who possess them, and that generalisations such as those offered in this section are only valid as far as they are useful.

3.2 Theoretical Framework

This section offers a brief additional comment on the theoretical framework which is specifically relevant for this section of the thesis research. As such it draws on the discussions of section 2.3 as well as the preceding literature review, and outlines how some of the key elements of the wider theoretical framework have been understood in the context of this particular group of learners.

3.2.1. Structure, Agency and Mathematical Qualifications as Cultural Capital

As discussed in section 2.3.1, this thesis has adopted the position that structure and agency are ontologically interdependent and irreducible (drawing on Giddens 1976). A localised example of this interplay can be seen in the unit of a group of adult learners of numeracy, wherein learners can be argued both to contribute to, and to be steered by, agreed codes of practice. Although this interaction between rule-following and rule-negotiation can be argued to be present in any group of learners, the literature above concerning good practice in adult basic skills education suggests that it is ostensibly more visible, and even more acknowledged within this sector.

This thesis also adopts the position that mathematical learning and qualifications contribute to an individual's cultural fund (drawing on Bourdieu 1973), and that the pursuit of these goals also involves both structure and agency; for whenever an individual may respond to societal expectations and pressures by seeking to attain cultural capital in this manner, they also act as part of that society, by approving and reinforcing the value of the very same learning or qualifications.

3.2.2. Identities of Adult Learners of Mathematics

As discussed in section 2.3.2, this thesis has adopted the position that identity is neither wholly essential nor wholly intrapsychic, and that the act of narrative is part of the related processes of identity construction and negotiation (drawing on Bruner 1996). This position has a direct impact on the methodology which follows in the next section.

Identity is a recurrent theme within some recent research into adult education. For instance Schuller (2004) links the concepts of identity and capital by proposing a theoretical triangle of three capitals: "the simplest way to address our analysis is therefore to think of learning as a process whereby people build up – consciously or not – their assets in the shape of human, social or identity capital, and then benefit from the returns on the investment in the shape of better health, stronger social networks, enhanced family life, and so on" (p.12). Whilst this framework offers much, and has been constructively used in related studies into adult literacy and identity (for example Crowther, MacLachlan and Tett 2010,) it does not fully fit with the overall aims or theoretical position of this thesis. It narrows the focus of the research by concentrating the analysis almost exclusively onto the learner; further, by conflating the concepts of identity and capital it depreciates the former and moves the latter away from the critical theory notion as originally posited by Bourdieu. This thesis therefore retains the previously stated position that whilst the perception, acquisition and desire for cultural capital are likely to be key components in the construction and negotiation of a learner's mathematical identity, identity as a concept is qualitatively different from any of the forms of capital which might be discussed. As part of this position this thesis recognises and utilises a selection of the analytical tools of inquiry presented in section 2.3 including ‘figured worlds’ (Holland et al. 1998) and communities of practice (Lave and Wenger 1991).

3.3 Methodology

The global research questions of this thesis were localised in section 3.0 and described as follows:

- **Who are the prodigals?**
- **What motivates the prodigals to return to learning mathematics; in particular, what roles or goals are at play in these decisions?**
- **How do the prodigals’ experiences of learning mathematics as an adult compare to, and contrast with, their experiences of learning mathematics at school? What changes are there in the ways that the goals and roles of mathematics education are navigated or made sense of by these learners?**

As these questions incorporate both quantitative and qualitative aspects, a mixed-method approach was chosen; the term is used here to denote methodological pluralism and pragmatism, and is deployed in support of a critical paradigm rather than being indicative of a new emerging paradigm (Cohen, Manion and Morrison 2011, pp.21-26). First, a targeted questionnaire was selected as a tool that could efficiently gather basic information about demographic characteristics and educational history. To counter the limited depth of response offered by this tool, the questionnaire was followed by a series of interviews. Participants for this interview stage were chosen on the basis of the questionnaire responses, so as not only to establish and report narratives that had their own intrinsic value, but to investigate also commonly observed themes and concepts, and in turn support claims of convergent validity (ibid., p.189).

3.3.1 Sampling and Access Issues

The diverse nature of adult learners of mathematics, as discussed in section 3.1.1, makes it difficult to construct any form of definitive sample. For this research I chose to approach further education institutions to establish a convenience sample. Whilst this was a pragmatic decision, there is evidence that a significant proportion, if not a definite majority, of adult learners access mathematics education through such institutions; the 2006 report into the Skills for Life programme reported that "more than two million of the 2.4 million people taking up courses by July 2004 undertook them in further education" (House of Commons Committee of Public Accounts 2006, p.6). Nevertheless, it should be noted that this choice excluded groups of learners such as those who study independently; those who study with tutors; and 'hard to reach' populations such as the homeless, or those working in unaccredited or informal community groups. If access to such learners could be negotiated, the stories of these prodigals would merit further research in the future.

Further education centres were selected in two contrasting regions, in an attempt to increase the range of backgrounds included in the sample. The first region was non-metropolitan; access to learners was negotiated through an institution that served as a major provider of adult courses. The second region was centred on a major city, within which there were a number of extant mathematics and numeracy study groups, linked to a central organisation. Groups for inclusion in the sample were selected through negotiation with staff, taking into consideration the background of the participants to ensure that the working definition of ‘prodigal’ was satisfied. Groups were either studying towards a numeracy qualification or a GCSE qualification; although one group was studying towards a GCSE-equivalent similar to that discussed in 3.1.2 there were no significant differences found between the reports of these learners and those studying towards a standard GCSE, so the term ‘GCSE’ is used from this point as an umbrella term.

Access was willingly granted by gatekeepers on the condition that an anonymised summary of the research was shared after the fact. Adult numeracy groups were visited in person, and the questionnaire was carried out with the researcher present. The GCSE groups however were close to taking their final exams so alternate access was negotiated with the gatekeepers. The tutor of one region’s cohort distributed and collected their learners’ questionnaires, ostensibly in line with agreed confidentiality protocols. Whilst this may have restricted participants’ openness, a comparative analysis suggested that any such influence was minimal. The other cohort was accessed via post, with questionnaires returned directly to the university in pre-stamped, addressed envelopes. This resulted in a return rate of 52%. In total, 73 completed questionnaires were collated. Five participants indicated that they had been schooled overseas and were removed, leaving the eventual sample described in table 3.4 below[1].

[1] This sample is two larger than that reported in Ward-Penny (2009) since two postal questionnaires were received much later than the others and were thus not included in the preliminary write up.

	Region A	Region B
GCSE or Equivalent	15	26
Numeracy Groups	19	8

Table 3.4: Composition of the Prodigals Sample

Six participants were selected for the subsequent interview stage through purposive sampling (conducted in terms of responses and demographics); in each case permission was granted directly by the individual. Of these six, one was unable to attend an interview for practical reasons; they were replaced by a participant with comparable responses. However, the replaced participant was still willing to take part in the study, and submitted answers to an edited form of the guideline interview questions by e-mail.

3.3.2 Questionnaire Design, Pilot, Application and Evaluation

The questionnaire was framed in three sections: section one concerned the participant's gender, age and educational history; section two was based around the decision to take a mathematics course; and section three was designed to survey and compare the participants' experiences of learning mathematics at school and as an adult. Although this design contradicted common advice suggesting demographic questions are left until last (for example Peterson 2000) it reflected the three localised research questions, as well as the relative import of the questionnaire over the interview in addressing the first of these. The majority of the questions in section three utilised five-point Likert scales to gauge participants' opinions on aspects of teaching and learning; whilst this design gave rise to associated problems such as assumptions about equal intervals and central tendency bias (Cohen, Manion and Morrison 2011, pp.386-390) it did facilitate comparisons supportive of the third localised research question. The reasoning behind individual questions is offered alongside the results in section 3.4, and a complete copy of the questionnaire is provided in appendix A.

The questionnaire was piloted with five prodigal learners whom I had met separately; their contexts meant that they would not be included in the final sample, and any incurred personal or social desirability bias was of limited concern as their responses were only gathered to assess the fitness of the instrument, not to contribute to the final results or analysis. The pilot participants indicated by answering some additional questions that the questionnaire was suitably straightforward to fill in, and that it took a mean time of 8.5 minutes which was also deemed acceptable. They also recommended some minor changes to the wording of questions, and suggested that there should be greater guidance on completing the Likert scales if a question was not applicable to the individual participant; this advice was heeded although some problems persisted. The pilot responses were largely indicative of the type of data that the questionnaire was intended to generate. In particular the responses of the 'at school' and 'as an adult' questions in section three were shown to be interconnected: excluding non-response, the pilot responses for the 'at school' Likert scales in 3a, c, f and g reported a Cronbach's α value of 0.844, and the 'as an adult' Likert scales in 3a, b, c, f and g reported a Cronbach's α value of 0.841. Whilst this statistic can be interpreted variously (Field 2009, pp.675-6) and it would be naïve in the extreme to suggest that the experience of learning mathematics is unidimensional, this did serve as a partial indicator of instrument reliability. After collection, the questionnaire data was coded and analysed using SPSS.

3.3.3 Interview Design, Application and Analysis

The interview tool was chosen to complement the questionnaire, so that preliminary conclusions might be challenged and a deeper understanding reached, in line with grounded theory expectations (Glaser and Strauss 1967). Seidman (2006) states that the root of in-depth interviewing is "an interest in understanding the lived experience of other people and the meaning they make of that experience" (p.9). This awareness guided the form and application of the interviews; a semi-structured approach was chosen to afford each participant sufficient control of the narrative that they could independently raise issues and offer markers of their own identity, whilst still facilitating a useful and valid degree of comparison in the consequent data. The structure was also designed to limit interviewer bias, although it can be argued that the intersubjective nature of conversation (for instance Kvale and Brinkmann 2009) means that a researcher can at best recognise and constrain such bias through the use of structure. A set of eight questions was constructed, reflecting and reinforcing the content of the questionnaire, and these are presented below in section 3.5. Further, if a participant had written something particularly interesting or unclear on their questionnaire, additional questions or shifts of emphasis were added onto a prompt sheet before the interview.

Six interviews were conducted as originally planned, with a seventh conducted by e-mail (see above). An additional short discussion with two adult learners at once was conducted after one interview subject met a friend who had been on the same course. Each interview took place in a location chosen by the subject; most interviews lasted between ten and fifteen minutes.

After transcription, the interview data was analysed using a method of coding and sorting that drew not only on grounded theory but the phenomenographic tradition. This tradition seeks to manage data arising from individual experiences by sorting features qualitatively into broad categories, and its ideas have been observed to fit well with the semi-structured interview model (Marton 1994). Thus broad ideas and themes from the questionnaire were integrated into the interview process, and the refined ideas and themes that emerged offered a framework for analysing the data and reporting the findings. Only one subject, namely the influence of setting on learners' motivation and achievement at school, arose unexpectedly. After being judged of significant import in both of the first two interviews, this topic was integrated into the remaining interviews.

3.3.4 Ethics

This research was designed and carried out in line with university guidelines regarding ethical research (the ethical approval form is reproduced in Appendix B). As a matter of respect, and in line with the democratising ethos of critical theory, measures were taken at each stage to involve, respect and protect the participants: learners were introduced to the purposes and design of the research before being asked for informed consent; there were clearly indicated opportunities for participants to opt out; and steps were taken to stress the optional nature of participation. It was also felt that it was important to share the goals of the research using readily understood terms; groups were told in the first instance that the aim was to "find out about your stories of mathematics, so we can try to improve the stories of others in the future." Further details of the PhD and the research process were then given to any participants who enquired.

A key aspect of ethical practice in this research was the maintenance of anonymity. In the first instance, participants were asked only to write down identifying information on the questionnaires if they were willing to be contacted, so many were instantly anonymous. In order to confer another level of global anonymity, all participants were allocated a four digit code before their data was entered onto any computer. Any identifying names of individuals or institutions were replaced by asterisks during the transcription process and perhaps most critically, confidentiality was maintained by making sure that no individual could be identified in any of the summaries produced for centres.

3.3.5 Validity and Reliability

As discussed in section 2.5.3, the concepts of validity and reliability are variously understood within critical paradigms of research. Nonetheless, measures were taken at each stage to bolster claims of validity and reliability for this component of the research.

The internal validity of this study was enhanced through the use of multiple tools to study the same concept; for instance, if a participant said in their questionnaire responses that the course had improved their 'confidence', the scope and context of this term would be explored in the interview, thus affording some degree of triangulation. A comparison of the interview transcripts with the questionnaires was also used to test internal consistency on the part of the participants.

Content validity was tested when the questionnaire was piloted; that few areas of concern or additional comment were uncovered at this stage or during the main research suggests that the tools contain fair coverage of the features which participants deemed salient. However, there are some persistent concerns about descriptive validity. In this study, the participants are reflecting on historical events which often had less than positive consequences; this, and the imperfect reliability of human memory, calls into question the fidelity of their accounts. This is unavoidable, but is recognised in the analysis below, particularly in the discussion of blame and responsibility (see section 3.5.2**).**

The scale of this research belies any absolute claims of external validity or generalisability, but some steps have been taken to extend the relevance of this study beyond its immediate context. All concepts and variables have been described explicitly and the sample, whilst not strictly representative, is deliberate, purposive and includes multiple groups of learners, demographic backgrounds and geographic regions. Further, Kvale and Brinkmann (2009) have claimed that "in post modern conceptions of social sciences the goal of global generalization is replaced by a transferability of knowledge from one situation to another, taking into account the contextuality and heterogeneity of social knowledge" (p.171). Whilst this may be a contestable position, it does recognise the individuality of data centred on the experiences and opinions of individuals, and awards it the possibility for relevance beyond the studied sample, as long as the data is considered in light of social factors pertaining at the time. It is in this sense then that this research aims for some generalisability, both as educational research concerning adult learners and as an episode of the wider thesis.

Practical steps were also undertaken to maintain claims of reliability. Checks were made to the interview transcripts throughout the transcription stage and during the coding stage in order to encourage consistency, and the semi-structured nature of the interview itself forced a greater degree of regularity in the processes of gathering and analysing the interview data. A partial indicator of instrument reliability was devised, involving the calculation of Cronbach's α for the Likert scales of the questionnaire (see section 3.3.2 for details and a discussion of interpretation). For the full sample, the Likert scales named 'at school' had 49 of 68 valid complete responses (19 or more participants had left one of more of the scales blank) giving $\alpha = 0.883$ on 7 items. The Likert scales named 'as an adult' had 59 of 68 valid complete responses giving $\alpha = 0.835$ on 7 items. These values are similar to, or better than those obtained in the pilot. In addition, Question 3g was used as a further synoptic check on instrumental reliability and this is discussed in section 3.4.6.7 below**.**

3.3.6 Researcher as Instrument

In line with the discussion of critical grounded theory section 2.4.2, a constant feature of this analysis was reflexivity on the part of the author. In addition to personal reflection, the support of supervisors and the presentation of this research at a meeting of the British Society for Research into Learning Mathematics (documented in Ward-Penny 2009) were put in place to expose categories and findings to the scrutiny of others, and guard against personal bias.

My own personal experiences and understandings of mathematics education may have supported my recognition of salient issues and strengthened shared meanings and intersubjectivity during the research process; contrariwise they may have biased the analysis process. For instance, I had little direct experience of formal adult mathematics education before this project although my personal encounters (such as those offered in section 3.0) and my position as a secondary mathematics teacher may have increased my empathy towards the teachers of adult education. Similarly, my personal beliefs about mathematics education and my previous experience of the dominance of the role of mathematics as a gatekeeper may have made me more attuned to signs of this primacy. In both of these cases however I contend that the weight of the evidence supports the associated findings presented above, even if they had been in part anticipated by the researcher.

3.3.7 Literacy and Language

During both the design and piloting phases of the questionnaire, steps were taken to maximise both the clarity and accessibility of the instrument. Nevertheless, in the responses to the open questions there was a marked difference in the lengths of the participants' answers between the GCSE and numeracy groups; this could be understood as signifying different levels of literacy. Although this concern was somewhat ameliorated by the use of the complementary interview tool, a deliberate attempt has been made to compensate and promote equality of attention in both the analysis and reporting of this research.

Transcription is frequently problematic; for instance Seidman (2006, p. 116) notes that even choices about punctuation can be significant when establishing the meaning and intention of a participant. However, accuracy is not the sole measure of validity, and after consideration it became my view that I had transcribed a number of comments in a manner such that the style distracted the reader unhelpfully from the underlying ideas and thoughts, and detracted from the weight of the quote. Therefore this thesis includes minor edits in cases where I felt confident of the intention of the speaker. As an example, consider the following quote:

Erm… like you said, money, money I can, obviously I can get around money now, time, erm… travelling, if I was to travel… erm, scale, I could do scale now, no problem. And just things like that – I'm more, I know how to do them now. Maybe I'm not probably perfect, but erm.. I know, what, if you talked to me about it, then I think, "yeah, I know what you're talking about."

This might be reported henceforth as follows:

Like you said, money – obviously I can get around money now. And time, and travelling, if I was to travel, erm… scale – I could do scale now, no problem. And just things like that – I know how to do them now. Maybe I'm not perfect, but if you talked to me about it then I'd think, "yeah, I know what you're talking about."

In recognition of this tolerance, the analysis in this chapter does not involve any substantial linguistic or syntactic analysis that would be undermined by this level of modification.

3.4 Questionnaire Results and Analysis

The first section of the questionnaire was designed to ascertain the demographic make-up of the sample. Gender, age and previous educational history were included as they had been identified as potentially salient factors during the literature review; conversely, class and socio-economic background were not included, as there was little pre-existing data for comparison and they would have been very difficult to measure accurately. There were only minor completion issues for this section of the questionnaire; for instance, there was one case of non-response for the age question.

3.4.1 Gender

The results for gender are presented below in table 3.5.

			Course Type		Total
			Adult Numeracy	GCSE	
Gender	Female	Count	20	35	55
		% within Course Type	76.9%	83.3%	80.9%
	Male	Count	6	7	13
		% within Course Type	23.1%	16.7%	19.1%
Total		Count	26	42	68
		% within Course Type	100.0%	100.0%	100.0%

Table 3.5: The Genders of the Prodigals Sample

These results demonstrate the presence of a strong female bias in both adult numeracy and GCSE groups. The size of the bias is a little larger than that reported by Benn and Burton (1994) and much larger than that reported by Coben et al. (2007), although this latter difference may be partially consequent from the non-inclusion of learners here who had begun a numeracy course immediately after leaving school. Gender was not significantly linked to course type (χ^2 = 0.113, df=1, p=0.737, continuity correction used) or region (χ^2 = 1.522, df=1, p=0.217, continuity correction used).

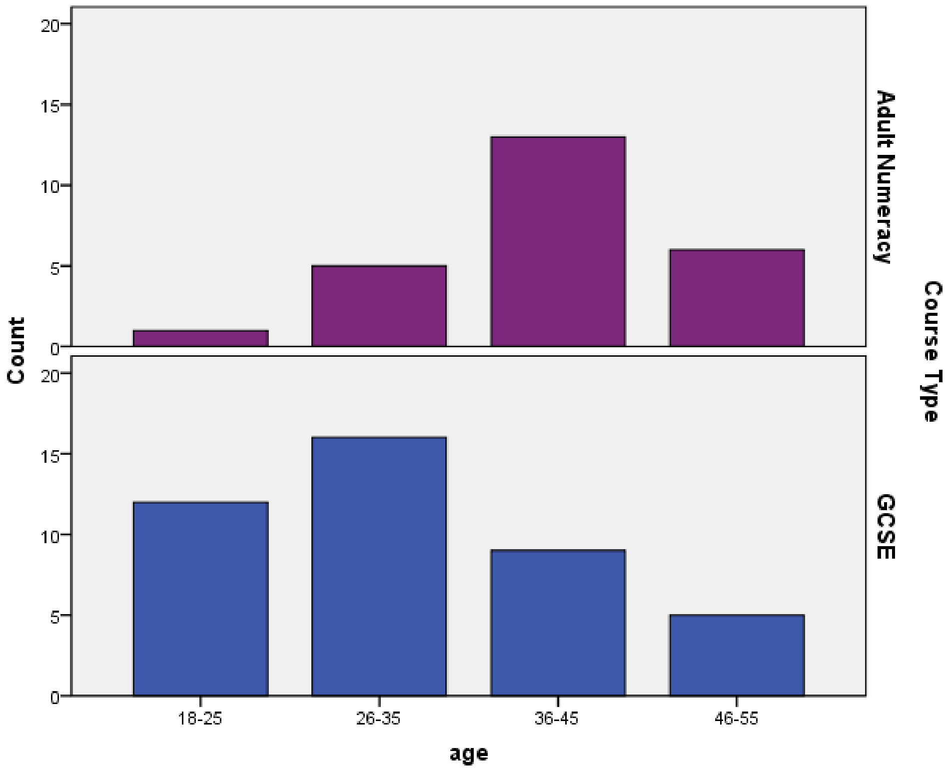
3.4.2 Age

The ages of the sample followed a roughly symmetrical distribution (table 3.6).

Age	Frequency
18-25	13
26-35	21
36-45	22
46-55	11
Non-Response	1

Table 3.6: The Ages of the Prodigals Sample

However, age showed a highly significant relationship with course type (χ^2 = 12.371, df=3, p=0.006), with the age profiles of adult numeracy and GCSE learners demonstrating negative and positive skews respectively (figures 3.1a and 3.1b overleaf). The positive skew might be understood as resulting in part from the gatekeeper role of the GCSE, as learners who had left school without a C grade or higher would soon find themselves encouraged to return and improve their result. These results do not seem to mirror the limited existing data discussed in 3.1.1, but any dissimilarities resist further comment since the samples and class intervals have been differently constructed.

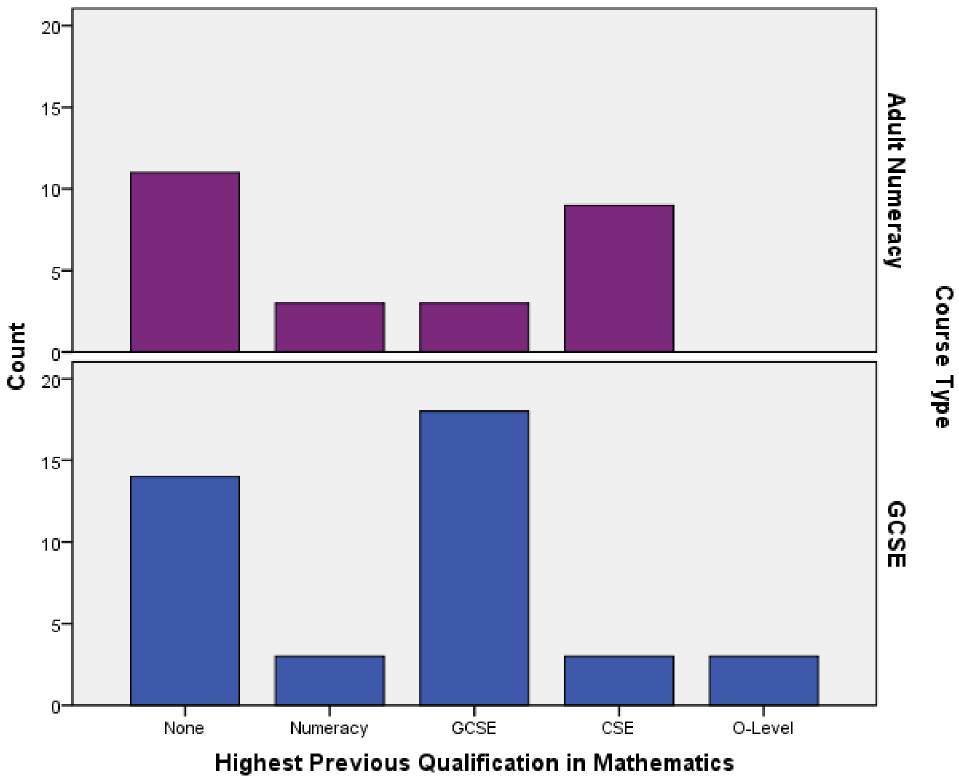


Figures 3.1a and 3.1b: The Ages of the Prodigals Sample Grouped by Course Type

No significant relationship was found between age and gender (χ^2 = 1.298, df=3, p=0.730). Although a significant relationship was found between age and region, loglinear analysis revealed this to be a consequence of the link between course type and region in the construction of the sample. Indeed, the questionnaire analysis did not uncover any significant differences between regions that were not more likely to be consequent from the different proportions of learners taking each type of course in the two regions, and so from this point the variable of region will be excluded from the reporting.

3.4.3 Educational History

The final question of section one of the questionnaire asked the participants to detail their previous formal education. For ease of summary and analysis, qualifications were used as summary indicators of educational history. Each question was presented as a series of tick boxes, with extra space provided for noting down any additional information. The participants were first asked about their previous qualifications in mathematics (figures 3.2a and 3.2b).



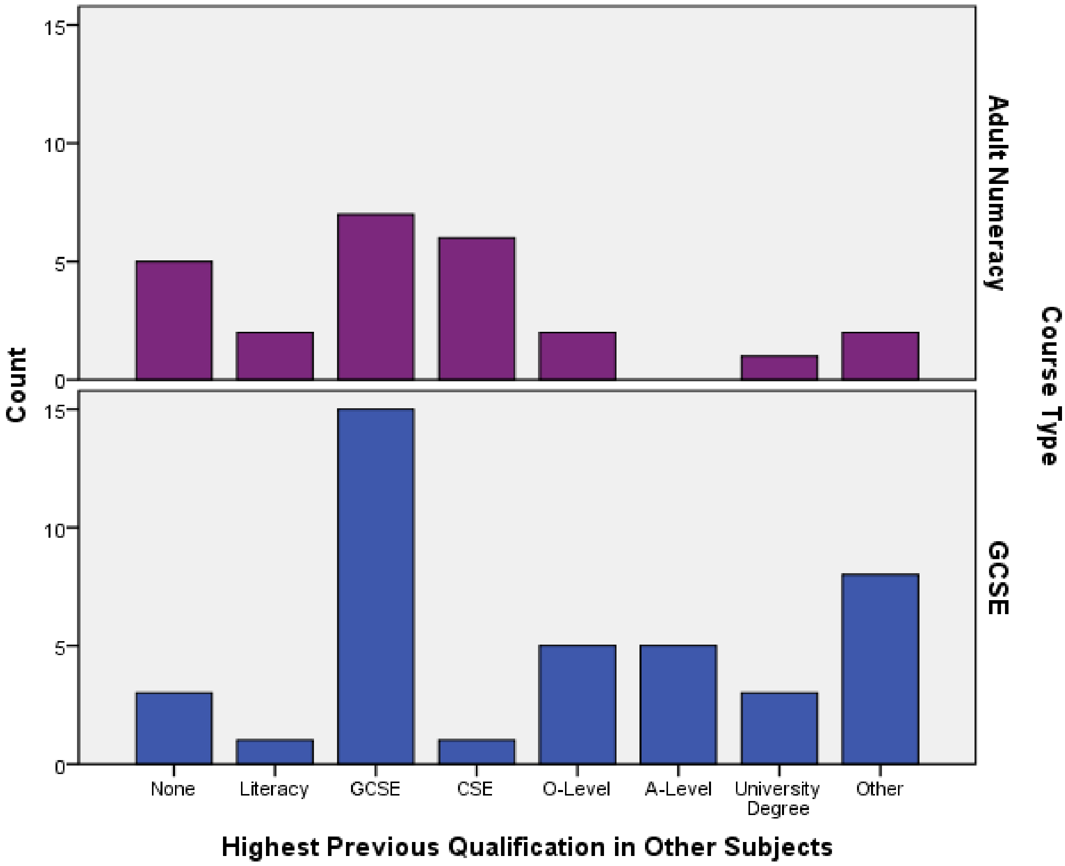
Figures 3.2a and 3.2b: Highest Previous Qualification in Mathematics Grouped by Course Type

The results demonstrated a wide spread and involved some striking features. First, 12 of the 26 participants on the adult numeracy courses had already achieved a GCSE or CSE qualification in mathematics. Conversely, 14 of the 41 GCSE level learners had no previous mathematical qualifications. These results together refute the existence of a uniform, hierarchical pathway in adult education from numeracy to GCSE, and foreground the importance of individual stories and motivations in understanding the actions of these learners. It is also interesting to note the modal response of the GCSE-level participants. Of the 41 learners, 18 had already attained a GCSE grade and were seeking to better it. That this was the case for almost half of the learners can be interpreted as evidence of the particular role that the higher grades of GCSE play as gatekeepers. That this proportion rises to more than half if CSE and O-level qualifications are included might also be taken to suggest that there is a related benefit attendant to recent exposure to, or qualification in, this level of mathematics.

The participants' wider educational history was diverse, with responses ranging from 'no previous qualifications' to one degree in fine art (figures 3.3a and 3.3b overleaf). It is thus hard to draw any conclusions from this range of responses other than to note that it belies any stereotype of adult numeracy learners as uneducated. The large number of GCSE mathematics candidates who were already qualified in other subjects to GCSE level or higher again supports the position that GCSE mathematics has some particular worth.

When asked about their previous experiences in adult education, 84% of those taking an adult numeracy course reported that they had attended a previous adult education course, compared with only 29% of the GCSE mathematics learners. This result was highly significant ($\chi^2 = 17.110$, df=1, $p<0.001$, continuity correction used). The most commonly reported courses were literacy courses and

ICT courses such as CLAIT; there were also three mentions of NVQs relating to child care and child development.



Figures 3.3a and 3.3b: Highest Previous Qualification in Other Subjects Grouped by Course Type

Together, these demographic questions on gender, age and previous educational experiences suggest that the 'prodigals' group is very diverse. However, within this variation there do appear to be definite trends related to the two levels of course studied. This observation supports a continued split in the presentation and analysis of the questionnaire results, and suggests that it might be valid to consider that there might be more than one 'type' of prodigal.

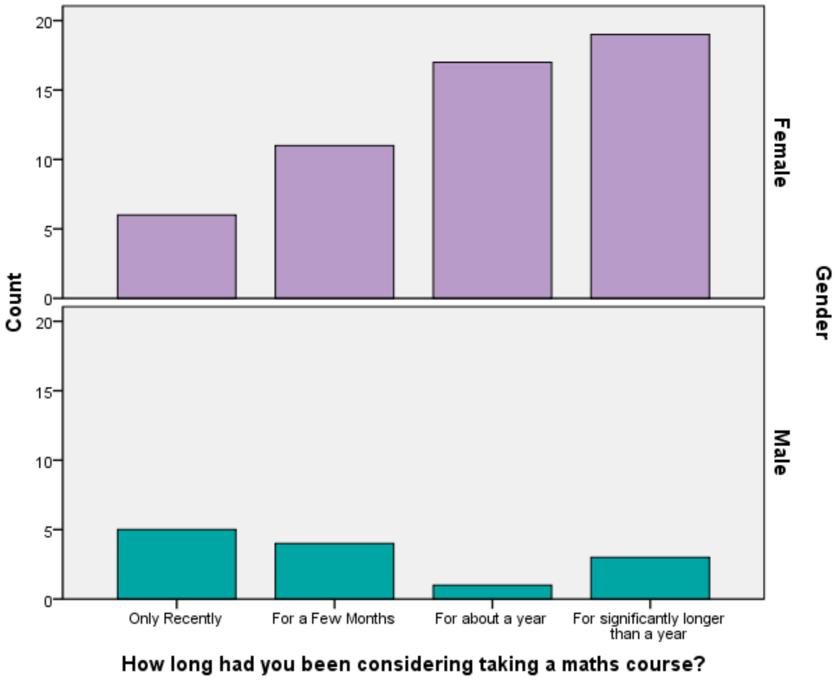
3.4.4 The Timescale of the Decision to Return to Mathematics

The second section of the questionnaire began by looking at the timescale of each learner's decision to return to the formal study of mathematics. Although it is beyond the potential of a single questionnaire to comprehensively explore the 'gradual and sudden' model offered by the literature in section 3.1.3, it was possible to record the learners' recollections of their decisions. The questionnaire asked the participants to select one of four boxes which best represented how long they had contemplated taking part in a course before enrolling; the choices were phrased using loose language as precise boundaries may have been unhelpful to participants.

How long had you been considering taking a maths course?	**Proportion**
Only recently	17%
For a few months	23%
For about a year	27%
For significantly longer than a year	33%

Table 3.7: How long had you been considering a maths course?

The overall results, presented in table 3.7, demonstrate a definite skew towards longer time frames; the notion of a mathematics course featuring as a component of a long-term plan is discussed further in the interview results and analysis below. There was no significant relationship between the response to this question and course type (χ^2 = 1.262, df=1, p=0.738) but the relationship between the response to this question and gender was statistically significant (χ^2 = 7.861, df=3, p=0.049), and a graphical representation of the results certainly suggests the overall negative skew is primarily resultant from a negative skew in the responses of the female participants (figures 3.4a and 3.4b).



Figures 3.4a and 3.4b: How long had you been considering a maths course? by Gender

3.4.5 Motives for Returning to Mathematics

The next question asked the participants to offer which factors had contributed to their decision to take a mathematics course. The list of suggested items was drawn from previous research studies such as Coben et al. (2007) and informal discussions with prodigals whom I had met and talked with prior to beginning the research. However, simple lists of items such as that contained in Coben et al. (ibid.) arguably have a limited scope, as motives are not all equally important in the decision making process. This inequity is often subtle, arising from the timescales of which goals operate; life goals are often harder to ascertain than short-term goals, and actions can be ambiguously or even unconsciously motivated. The complexity of the decision making process was explored during the interviews, but as a first step towards establishing the priority of certain motives, participants were asked to select as many items as they wanted to, but also to circle the factor that they felt was most important. A significant amount of space was then added beneath the list to allow participants to add further details about their decision if they wished to. The twelve items, together with the thirteenth ‘other’ option which participants were able to detail, are reported overleaf in table 3.8 (items were not numbered on the questionnaire).

These results offer further evidence for the position of GCSE mathematics as a gatekeeper, with the modal motive for the GCSE cohort being that the qualification was needed to make further progress in adult education. By way of contrast, intrinsic motivations and personal development motives such as items 1, 2, 6 and 11 scored highly with numeracy learners. In line with the findings of Coben et al. (2007) the motive of wanting to help children was linked to gender; of the 26 participants who selected this motive, 23 were female. The reasons offered under ‘other’ tended to reword motives already described.

Item	Motive	Frequency (Numeracy)	Frequency (GCSE)	Frequency (Total)
1	I wanted to be able to help more with my children's schoolwork	12	14	26
2	I wanted to learn more maths to help me get by at work	12	15	27
3	I was encouraged to do it by my family	3	1	4
4	I needed a qualification to help me get a promotion in the job I have at the moment	6	2	8
5	I always felt like I had missed out on something at school	11	17	28
6	I wanted to become more able to use numbers on my own in everyday life	15	8	23
7	I needed a qualification to help me get onto another course	8	31	39
8	A maths qualification is necessary for a job I want to apply for	7	9	16
9	I was encouraged to do it by my friends	1	1	2
10	I wanted to improve my chances of getting a new job	10	13	23
11	I wanted to do it to help me develop in confidence	17	15	32
12	I wanted to do it for pleasure	9	6	15
13	Other (please state)	0	4	4

Table 3.8: Motives for Returning to Mathematics

Unfortunately, not all of the participants circled their primary reason as requested but, by incorporating incidents where only one reason was selected or the text made it clear that one of the selected motives had priority in the mind of the participant, 52 of the 68 questionnaires indicated the most important reason for returning to the study of mathematics. This data is summarised in table 3.9.

		Course Type		
		Adult Numeracy	GCSE	Total
What was the most important reason?	1	4	1	5
	2	0	2	2
	4	3	0	3
	5	3	0	3
	6	1	0	1
	7	3	22	25
	8	2	1	3
	10	2	3	5
	11	1	1	2
	13	0	3	3
Total		19	33	52

Table 3.9: Primary Motives for Returning to Mathematics

The most immediate result here is that 22 of the 33 GCSE candidates identified progression in education as their primary motive, whereas no other motive was chosen by more than three GCSE learners. The additional comments provided here further submit the strong influence of mathematics as a gatekeeper:

> *"It was a course requirement."* (GCSE Learner)

> *"I want to do a T.A. course, so I decided to improve my Maths in order to do another course."* (Adult Numeracy Learner)

> *"What I am trying to say is that I realised that most universities require at least a pass in Maths before you can be admitted to do any course."*
>
> (Adult Numeracy Learner)

The responses of the adult numeracy learners were much more varied, although intrinsic and personal development motives rated highly. Taking an adult mathematics course appeared to have helped both numeracy and GCSE learners with their confidence:

> *"Having done badly at Maths at school and always having had a hatred of Maths, I wanted to prove to myself that I could do it if I applied myself. I had to overcome my fear of Maths".* (Adult Numeracy Learner)
>
> *"I never liked Maths at school so doing this made me feel more confident in my Maths skills."* (GCSE Learner)
>
> *"Maths was the subject that held most fear for me. I feel more confident with maths now and have even considered doing advanced maths. The tutors have given me the time and patience which has helped my confidence."*
>
> (GCSE Learner)

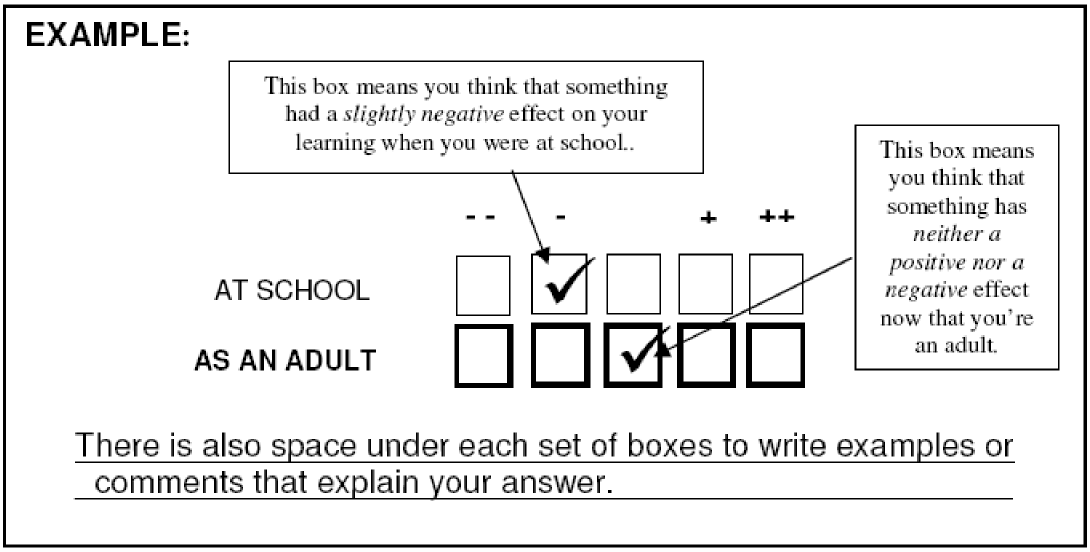
Whilst the tone of most of the comments throughout the questionnaire was generally positive, there were some exceptions. For this participant the imposition of mathematics as a gatekeeper would appear to have engendered resentment:

> *"Wanted to do a university degree, needed 5 GCSE passes to go onto A-levels to then move to a degree. 'Mature student' is no longer a relevant entry route due to political correctness – I did not want to do this course."*
>
> (GCSE Learner)

In summary, section two of the questionnaire once again demonstrated significant differences between the prodigals taking numeracy courses and those studying towards a GCSE qualification. Enquiry into the timescale of the decision suggested that most learners (particularly females) had considered returning to mathematics for some time, although this does not rule out the existence of a 'trigger' event for some or all learners, as discussed in section 3.1.3. In the global terms of this thesis, the responses about the motives behind the return to mathematics continually suggest that prodigal learners are primarily responding to the role of mathematics education as a conduit to a gatekeeper qualification, although there is some reported awareness of many of the associated goals as well. These issues are all explored further in the interview results and analysis below.

3.4.6 Learning Mathematics at School and as an Adult

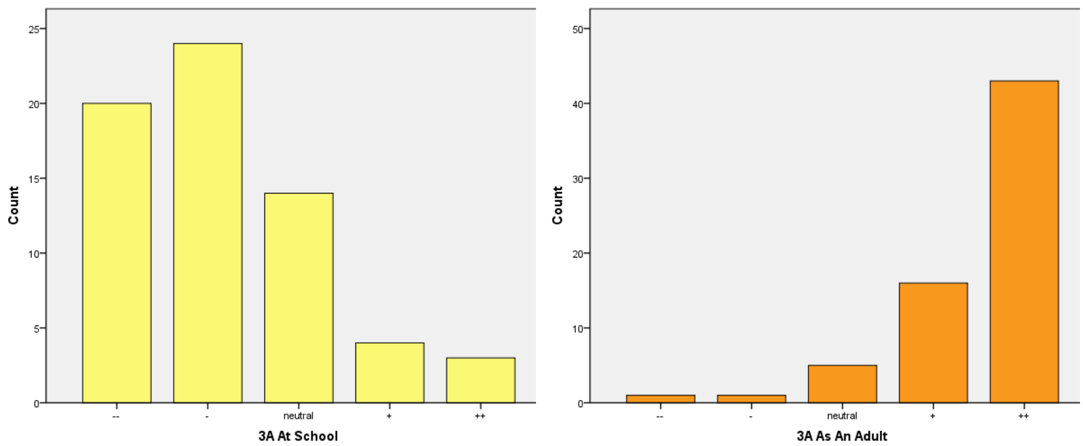
The final section of the questionnaire required participants to reflect on their experiences of learning mathematics at school and as an adult. Learners were asked to report whether they felt seven particular aspects had impacted positively or negatively on their learning using paired Likert scales. These scales were introduced with some guidance, reproduced overleaf:



Despite this direction, this manner of question design still resulted in some minor difficulties. Four participants did not fill in the boxes in a manner that could be fully understood, so these learners were excluded from the subsequent analysis. A small number of responses were received where the left-most box had been confused with a 'not applicable' response. A few participants consistently ticked the same response boxes for 'at school' and 'as an adult' although after consideration this was accepted as a genuine, if not fully considered, response rather than a misinterpretation of the instructions. Finally, the completed scales exhibit an almost unanimous perception of improvement in every respect, which could reflect a social desirability bias. Nevertheless, the results still serve to identify key characteristics of the prodigals' experiences of learning mathematics both at school and as an adult.

3.4.6.1 The Relationship with the Mathematics Teacher

Critical summaries of adult education, such as Hamilton and Hillier (2006), remark at length on the importance of a good working relationship between teachers and adult learners. It may therefore be seen as unsurprising that the participants in this research reported much more positive relationships with their teachers as adults than as school pupils (figures 3.5a and 3.5b).



Figures 3.5a and 3.5b: How would you describe the effect of your relationship(s) with your maths teacher(s) on your learning?

Of the 64 learners who completed both scales, only two indicated that they had found their teacher at school more helpful, rating 'at school' one point higher and offering no further information. Whilst in the additional comments there were some reports of positive school experiences, and some participants explicitly recognised that there had been a range in the quality of teachers at school, overall there was a noted improvement in the relationship between teacher and learner; the median change from 'at school' to 'as an adult' was an increase of 3 points on the scale, and the mean shift was 2.3 points. Although such quantitative measures should be interpreted carefully, this was the most pronounced increase of any item.

Many of the supporting comments offered further insights:

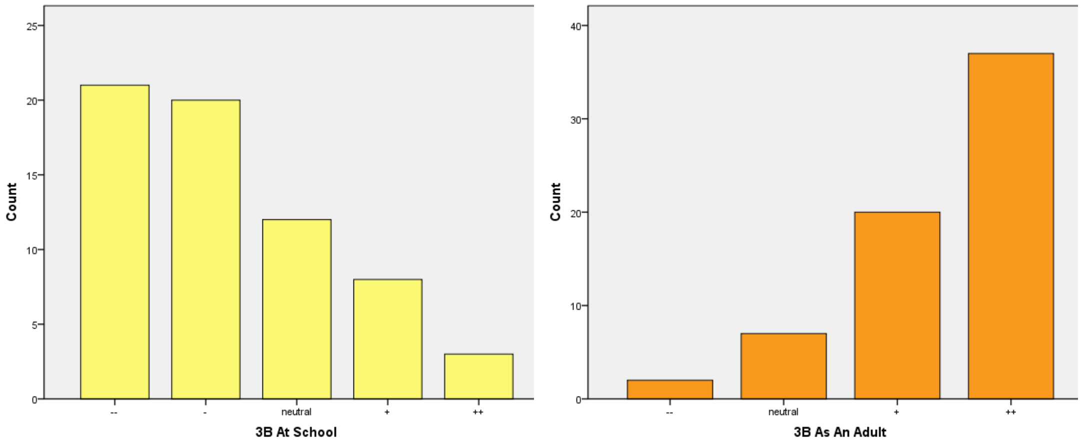
> *“I didn't have things explained at school, work was put in front of you and you were expected to do it.”* (GCSE Learner)

> *“Hated my school maths teacher. He didn't make maths fun. My current maths tutor is fantastic, if you don’t understand she will explain it in as many different ways as possible until you do. She also relates all our maths to everyday life.”* (GCSE Learner)

The scale of the shift in this item strongly supports the extant idea that the adult education teacher is an incredibly important figure to the adult learner, and thus it could be argued that such teachers are also potentially dominant sources of discourses regarding the purposes of mathematics education. However, the second quote above could be read in two ways. Is the maths tutor ‘fantastic’ and *also* someone who relates mathematics to real life, or is the tutor ‘fantastic’ *because* they relate mathematics to real life? The stronger relationship between teacher and learner observed here could indicate a vertical transmission of discourses regarding the purposes of mathematics education (Ward-Penny 2011), but it could equally be argued to be consequent in part of the teacher and learner possessing more sympathetic understandings of the purposes of learning mathematics.

3.4.6.2 Styles of Teaching

The range of interest of this item had significant overlap with the previous one, and it produced similar results. The general perception was that there had been a positive improvement in teaching style; the median shift was 2.5 points and the mean shift was 2.2 points (figures 3.6a and 3.6b overleaf).

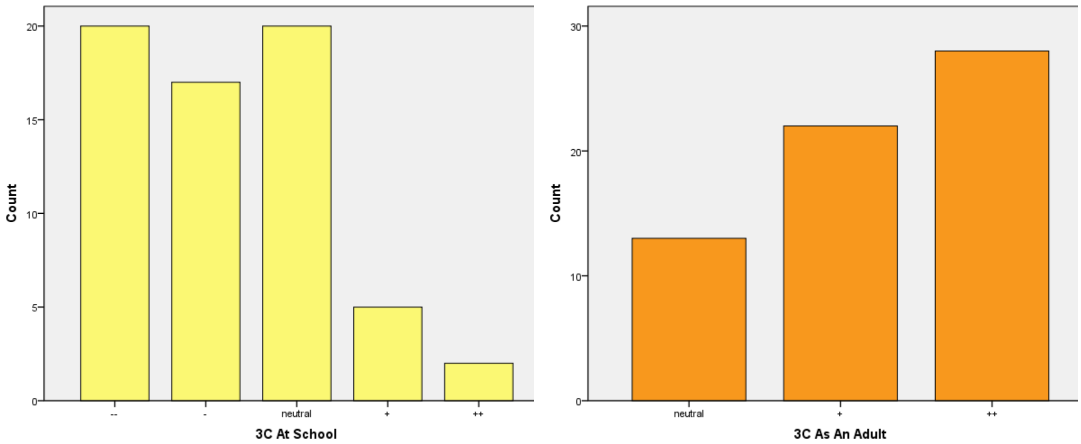


Figures 3.6a and 3.6b: How would you describe the effect of the style(s) of teaching used by your maths teacher(s) on your learning?

Some of the comments again touched on how contexts were being used to aid explanations: *"Lots of examples used by current maths tutor from real life to explain different aspects of maths"* (GCSE Learner). Pace was also mentioned: *"There is more time and explanation now and more support and teacher approachable"* (Adult Numeracy Learner). The comments were generally positive, with only two learners rating the style observed 'as an adult' to be unhelpful; one of these was the participant discussed in section 3.4.5 who resented having to study mathematics, whilst the other appears to have been a completion error in light of the written comments.

3.4.6.3 Tests and Assessments

This item was designed to explore whether learners perceived tests and assessments differently having spent some time away from formal schooling. It was unknown whether the primacy of the qualification for many learners would contribute to an increased sense of test anxiety, or a greater appreciation of the bearing and possible uses of tests and assessments. The results are summarised in figures 3.7a and 3.7b.



Figures 3.7a and 3.7b: How would you describe the effect of tests and assessments on your learning?

In summary, the reported perception was that tests and assessments were now a more positive feature of learning, with one learner even remarking that there had not been enough testing as an adult; the median shift was 2 points and the mean shift was 2.0 points. Some insight into this shift could be inferred from comments which suggested that assessment was now being used more formatively than had been the case at school:

> *"Never got much more than 40% at school, felt stupid but didn't know where I'd gone wrong."* (GCSE Learner)

> *"Learn a lot from the mocks, I use them to know what I need to brush up on."* (GCSE Learner)

Related to this were two comments which reflected on the strengths and weaknesses of different forms of assessment:

> *"As an adult learner, modular exams were better as I could focus on particular areas of maths."* (GCSE Learner)

> *"I believe that as an adult if given time you can solve a problem by working it out, sometimes tests are not a true reflection of ability."* (GCSE Learner)

Other comments began to reflect another emergent theme, namely the effect of setting and class organisation on learners' experiences and motivation:

> *"We always had tests and if you got low marks you got put in a low maths group it was awful."* (GCSE Learner)

> *"I was quite good at maths but was not allowed to go in the higher group because I was middle level at other subjects."* (Adult Numeracy Learner)

This theme is strongly indicative of the place of mathematics as a shorthand indicator of general academic ability, a role of mathematics education noted in section 1.2.3. The topics of setting and class organisation became much more prominent in interviews and are discussed further below in section 3.5.5.

3.4.6.4 The Use of Computers and Technology

The fourth pair of Likert scales asked learners to evaluate the effect of computers and technology on their learning. This was the most poorly answered item, with 16 instances of non-responses and a number of instances where 'not applicable' may have been confused with the left-most box, so this item has not been analysed quantitatively; further, it was not possible to separate fully the issues of access and agency. The comments reflected a substantial range of experiences and levels of confidence:

> *"Not really available as a child. Past practice papers available on internet and revision discs really helpful."* (GCSE Learner)

> *"I did not use computers at school. Now as an adult I am not confident using computers."* (GCSE Learner)

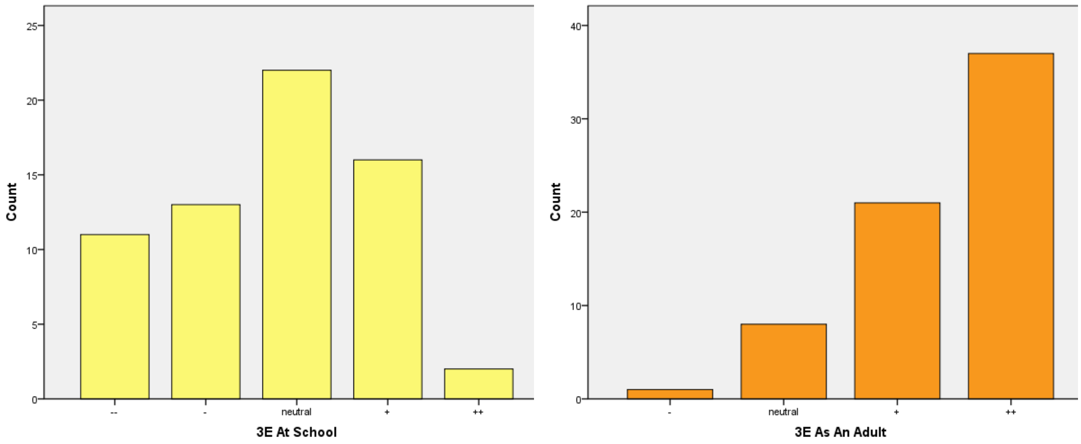
> *"I don't like computers and prefer writing. However current teacher uses some good powerpoints."* (GCSE Learner)

3.4.6.5 Working with Others

This item asked participants to reflect on their experiences of having the chance to work with others. Learners tended to review their school experience fairly neutrally, and although there was a positive improvement (median shift 2 points and mean shift 1.6 points) this was the second smallest reported (figures 3.8a and 3.8b overleaf).

Overall the participants seemed to find group work more common and natural as adults, although there was still evidence of individual preferences:

> *"As an adult: being in an environment with people in the same boat, a lot of help is given to each other, in classes. At school: disruption from students very off putting."* (GCSE Learner)



Figures 3.8a and 3.8b: How would you describe your experience of having chances to work with other learners?

"Didn't talk to people at school." (Adult Numeracy Learner)

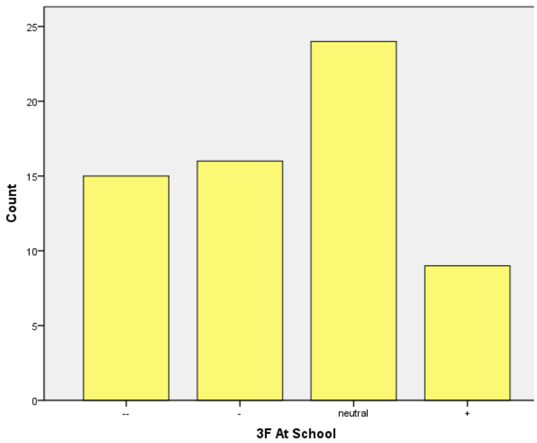
"Easier to work in groups but sometimes can concentrate on my own."

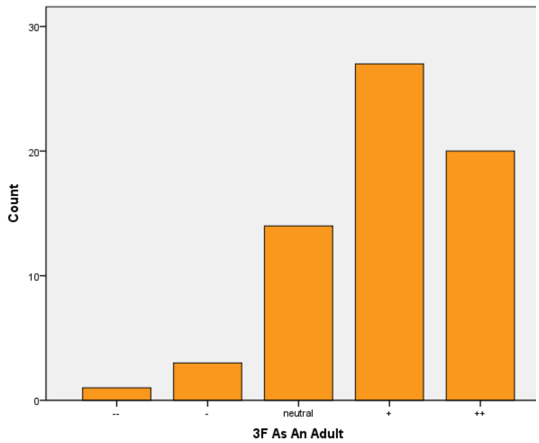
(Adult Numeracy Learner)

Although both ICT and group work are sometimes proposed as constructive features of pedagogy, the questionnaire results offered little in the way of evidence that these aspects of teaching and learning had contributed to these particular learners' mathematical identities or sense of mathematical purpose and so these elements were not carried through into the interview stage.

3.4.6.6 Real-World Mathematics

This question concerned learners' experience of working with 'real-world' mathematical questions and tasks. The results showed the most muted measure of improvement; the median shift was 2 points and the mean shift was 1.5 points (figures 3.9a and 3.9b). However, only four participants wrote additional comments, and just one of these from a GCSE learner directly referred to real-world tasks (*"As an adult learner, I could apply a lot of the questions to real-life situations/tasks")*; in light of the evident appreciation of contexts earlier in both the questionnaire results and also the subsequent interviews, it is therefore possible that this question was not fully understood as intended.



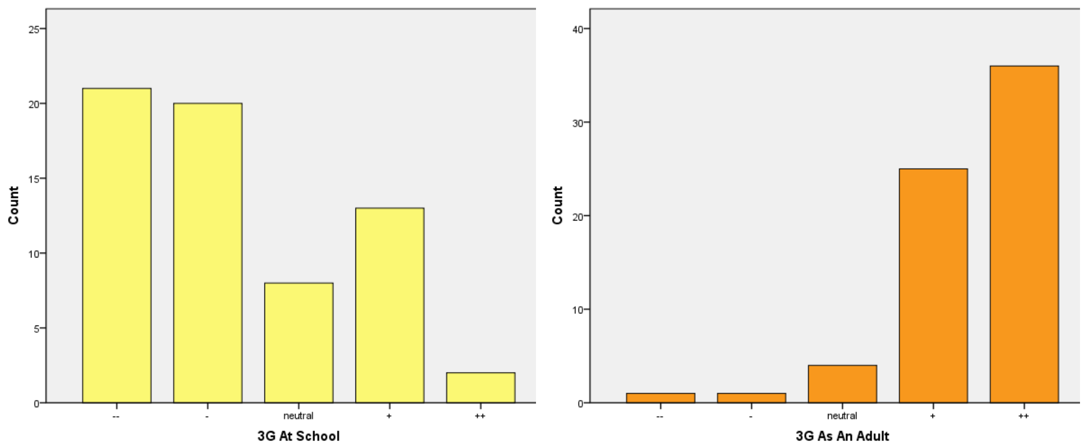


Figures 3.9a and 3.9b: How would you describe your experience of working with real-world mathematical questions and tasks?

3.4.6.7 Overall Learning Experience

The final pair of Likert scales asked learners to reflect on their overall experience of learning; the results are presented overleaf in figures 3.10a and 3.10b.

This item facilitated some informal checks of internal instrumental reliability; for instance the responses to both of these scales correlated positively, strongly and significantly (0.722 for 'at school' and 0.729 for 'as an adult') with an average of the corresponding responses to the previous items (excluding the ICT item due to non-response). The median shift was 2 points on the scale, and the mean shift was 2.1 points; the result that the mean of the mean shifts from the previous items (again excluding ICT) was 1.9 points again suggests that the participants responded with a good degree of consistency.



Figures 3.10a and 3.10b: How would you describe your overall experience of learning maths?

The inclusion of this question also allowed learners to add any other comments which they might not have felt 'fit' into any of the previous categories. Together these comments reflected a general improved disposition towards learning mathematics:

> *"Hated maths at school but I love it now."* (GCSE Learner)

> *"I felt let down at school, I'm really enjoying learning now."* (GCSE Learner)

> *"Nobody was ever there to give one to one when needed in the class. Always felt like I was playing catch up in Maths."* (Adult Numeracy Learner)

> *"As an adult: for the first time in my life I actually enjoyed solving maths problems. Weird or what. At school: saw maths as pointless and senseless in the real world especially algebra."* (GCSE Learner)

The aim of asking participants to compare their school and adult education experiences in this section was to probe how the prodigals might see their own mathematical journeys, and also to highlight differences in opinion and changes in perception which might be understood as resulting from a shift in the balance of competing goals and roles. The results of this section as a whole are strongly demonstrative of the prodigals having a sense of their own mathematical trajectory, with the vast majority of participants consistently evaluating their adult experience of mathematics as more positive, more purposeful and qualitatively distinct. Further, despite their brevity and range, a fair number of the additional comments could be connected to the goals and roles of mathematics education and their associated discourses. As an example the final quote above includes, amongst others, markers of progression and breakthrough ("for the first time in my life"); the discourse that mathematics is not supposed to be enjoyable ("actually enjoyed" and "weird or what"); the discourse that mathematics is a nonconcrete intellectual pursuit ("pointless and senseless in the real world"); and a focused instance of this discourse ("especially algebra"). As such this quote is strongly indicative of a learner who has a sense of their own mathematical trajectory and who has adjusted their sense of mathematical purpose in light of new experiences.

3.4.6.8 Three Open-Ended Questions

The questionnaire concluded with three open-ended questions, included to encourage comments of a more general and more extended nature. In contrast to the sparse optional comments offered underneath the Likert scales, almost every member of the sample answered these questions in some detail.

The first question asked "what would you say is the most rewarding thing about learning mathematics as an adult?" The responses were sometimes ambiguous and often touched on multiple ideas, and so resist simple categorisation or tallying. Nonetheless, key themes were evident and are offered here, together with two examples of each theme:

- General self-confidence (*Self-confidence; It has been rewarding to change past negative messages.)*

- Confidence with mathematics (*Realising that it is not as difficult as I thought; The fact that after 30 years of thinking I couldn't do maths I can!!)*

- Being able to get on better at work or at home (*Being able to support and help my children with school work; More useful and easier to get on with everyday things*)

- Achieving a qualification (*Knowing that I can gain a better job by completing my Maths GCSE; I may take a course in Science, you need Maths for this type of course*.)

- Having a better experience of learning (*Wasn't treated like a child, more as an equal; Being able to ask the tutor questions and not feel silly.)*

- Enjoyment (*Good fun and experience; is amusing)*

The second question asked "what would you say is the most challenging thing about learning mathematics as an adult?" Again, the answers tended to repeat certain themes:

- Time pressures and other commitments (*Trying to fit it in around working and living!; Life! Still having to do life i.e.: children, shopping, cleaning etc.)*

- Memory (*Remembering all the facts/formulas etc.; I have a rubbish memory)*

- Overcoming fear and developing confidence (*Changing the way you think about maths and your ability; Having the confidence to start again at base level)*

- Specific mathematical topics (*Algebra; Fractions and percentages but they have been made easier by our eager tutor*)

The final question was more speculative, asking participants "if you could send one message back to yourself as a pupil in a maths class, what would it be?" The majority of responses tended towards a simple exhortation, such as 'you can do it', or an encouragement to behave differently, such as 'put the effort in'; the reluctant participant first discussed in section 3.4.5 went further, saying "Try harder! Coz it's as boring as an adult as it was back then!" A few comments such as “revise as you go along” were more specific and identified a key study skill; others such as “lose the attitude” seemed to imply some degree of self-criticism, with the bluntest comments of this type being written by male members of the sample. A good number included an element of blame or recrimination directed at the school, such as “Find a better teacher!!”, “Change schools.”, “Keep asking for more support and not being afraid of that horrible maths teacher and wishing the time and maths class would go away quicker.” and “Shout at the teacher and say ‘I want to learn leave all the naughty ones in another room.’”

The responses to all three of these final questions address the research aims of this thesis in a number of ways. In the first instance, the comments as a whole are consonant with, and supportive of, the wider findings of the questionnaire. Some of the responses to the first two questions further appear to reference directly a particular goal or role of mathematics education such as promoting a daily numeracy (*easier to get on with everyday things*), facilitating entry to higher education (*you need Maths for this type of course*), or the use of mathematics as a shorthand for general intellectual facility (*knowing that you're not stupid, you just didn't apply yourself at school)*; others centre on a learning behaviour such as memorisation which suggest how learners might characterise success in mathematical learning. Beyond this the number and nature of the comments that apportion blame, whether towards a prior school, teacher, or the learner themselves, advocate the existence of a high level of frustration and sometime resentment that is consequent of the impact that not having qualified at mathematics has had on many of the prodigals' lives.

3.5 Interview Results and Analysis

As outlined in section 3.3.3 the interviews were semi-structured, constructed around a set of eight questions which are reproduced here. These questions were finalised in light of the preliminary findings of the questionnaire. The first three questions were intended to inform the second local research question by exploring the decision making process in more depth than the questionnaire had allowed:

- *When did you first decide to take a maths course?*
- *What helped you make that decision?*
- *How important to you is the qualification at the end of the course?*

The next three questions were intended to inform the third local research question, by exploring the ways in which the learners had perceived the goals and roles of mathematics education, both at school and as an adult. All three questions were worded with the intention of encouraging the interviewee to reflect on and report changes in their perceptions, but the questions had three complementary foci: the learners' expectations based on what they had understood mathematics to be as a school pupil; their relationships with their teachers who had likely served as both mediators of purpose and models of mathematical activity; and finally their emotional reactions to mathematics as a subject area, and their opinions about what might have constituted, and what might now constitute, success for them personally in mathematics.

- *Did you find learning mathematics as an adult to be very different to what you expected? How?*

- *Was your relationship with your maths teacher very different now you're an adult?*

- *How has your confidence developed over the course? How did you feel about maths at the beginning/middle/end of the course?*

The final two questions were included to bolster convergent validity and investigate any outstanding questions or items specific to the individual participant:

- *Go over final three open-ended responses with participant for convergent validity / clarification – also explore any particular features identified in the purposive sampling.*

- *What do you think could have improved things for you at school so you didn't leave without the confidence and the qualification you wanted?*

The eight questions formed a guide for the interview, but did not fully dictate either its content or structure; the primary objective was to explore and record the experiences of identified prodigals, and the flow of the participants' narratives frequently shuffled the order of the questions. Further, in light of the questionnaire findings the topic of setting and class organisation was assimilated into the interviews, but this was not explicitly integrated into the wording of the set questions; given the particular resonance of this topic with some of the aims of mathematics education it was felt that an extra level of understanding could be gleaned by observing if these issues arose without prompting, and in what context.

A new group of participants was fashioned which loosely represented the wider sample in terms of both demographics and key issues. This dual goal did necessitate some compromise; for instance, the 36-45 age group was not represented. The eventual sample is outlined below in table 3.10, alongside the codes used in all following transcript excerpts. The letter ‘I’ is used below to indicate the interviewer, and ‘H’ to refer to the female GCSE learner who joined in at the end of the interview conducted with participant ‘D’.

Participant	**Course Type**	**Gender**	**Age Group**	**Key Issues**
A	Numeracy	Female	26-35	Confidence; strong contrast between school and adult experiences
B	Numeracy	Female	46-55	Needed the qualification to progress in job; talked about a ‘mathematical way of thinking’
C	Numeracy	Male	26-35	Confidence; male learner
D	GCSE	Female	26-35	Had made significant life changes to enable access to the course; wanted to help children
E	GCSE	Female	26-35	Needed the qualification to apply for a job; most challenging thing was ‘making the decision’
F *(by e-mail)*	GCSE	Female	26-35	Needed the qualification for another course; memory; balancing real-life
G *(replaced F)*	GCSE	Female	26-35	Needed the qualification for another course; memory; balancing real-life; fear of maths

Table 3.10 Composition of the Interview Sample

3.5.1 Further Insight into the Decision to Return to Mathematics

The accounts of the prodigals' decisions to return to mathematics were very individualistic in many respects but there were also a number of significant commonalities. All of the accounts showed an appreciation of the many advantages offered by a mathematics qualification, but these were differently prioritised and expressed.

Participant A saw learning mathematics as a significant step towards improving their employment prospects and setting themselves up properly for life; in short, A demonstrated an appreciation of a mathematics qualification as cultural capital. A also wanted to pass this advantage on to her children: "I'm actually doing it for my future, and for my future with my kids as well." A was so determined to attain this capital that this was the second time she had actually gone to college; her first experience had not been successful (see section 3.5.2) so she had given up temporarily and returned for a second attempt later.

B had also demonstrated persistence in working towards her goals; she had been working towards a numeracy qualification for about three years, even attending two classes at once at one point. Her decision to return to mathematics was fuelled by a specific desire and goal for which mathematics was acting as a gatekeeper qualification:

I: You mentioned to me before something about wanting to be an HLTA?

B: Yeah, I'm going to do that now. Definitely going to go for that now in October.

I: OK. And do you have to have some kind of numeracy for that?

B: Oh yeah, you've got to have literacy and numeracy two, level two.

Conversely, participant C "didn't actually decide to take a specific maths course". Having chosen to return to college to improve his skills and employment prospects, he was studying numeracy as part of an umbrella course. However, he was aware of the potency of his study:

C: I thought, OK – maths was my weakest subject at school - by far - you know, if I'm going to get any sort of job in the future my maths has to improve…

C appeared to conceptualise numeracy as a natural and important step within the wider pathways of basic skills and adult education, although for him the numeracy certificate "personally didn't mean all that". His decision had also been aided by a certain practical factor:

I: So your focus in doing the maths course was to improve your job prospects, that sort of thing?

C: Basically, yeah, it just got me to a level where I maybe would be able to go back and do a college course on a particular subject, you know. It was also… I thought it was quite an easy way of getting myself back into the idea of learning.

I: OK, excellent. What helped you make the decision?

C: It were free!

Participant D was so convinced of the benefits and import of retaking GCSE mathematics that she had moved house. She wrote on her questionnaire that she had “looked at the local college for adult education and was not happy with that they offered. I was so determined to do this that me and my children moved almost 250 miles… I am so glad I did this.” Similarly to many of the others, D viewed mathematics as fundamental to making progress:

D: And then when I sat down and thought about it I thought, well, you need maths for everything, so I might as well do it again.

However, she reported that her primary motivation was her family; her whole interview is in some ways reminiscent of the ‘gradual and sudden’ model of the decision making progress discussed above:

D: The thing that kicked it off in my mind was when my daughter came home with some simple fractions and stuff, and she was only like four or five at the time, and I’m sat thinking, ‘I can’t do that! Oh my god – how do I do that?’– I couldn’t work it out in my head and I thought, ‘what happens when she comes back as a teenager and says, “Mum, can you help me with this?” and I’m like, “Hmm… no, I can’t do it.”’

I: So it was important for you to get it so you could help your kids?

D: Yeah, definitely.

The remaining interviewees had all needed GCSE mathematics to progress with their wider studies. Participant E had just finished taking a degree in early childhood studies and had essentially been forced to return to learning mathematics. She reported that the decision to return to the mathematics classroom had been the most challenging thing about the whole experience, as she was afraid that she would be too old to be on the course; this is provocative, as if she had not overcome this fear the role of mathematics as a gatekeeper qualification would have effectively vetoed her entire degree.

Participant F's decision making process was resonant with those of D and E:

F: I was considering going into Primary School teaching which you need GCSE Maths for. I also wanted to improve my maths as I have a 21 month old daughter and want to be able to help her with her maths homework when she's at school.

G wanted to do midwifery at university and needed the right set of qualifications to apply; the timing of her decision had been influenced by her family:

G: The youngest is just about to start school this year, the middle one started school last September, so I thought I'd probably be able to fit it in a bit better than I would have done before. I just wouldn't have really had time before to be honest.

In summary, these decision making processes support the findings of section 3.4; the interviews reiterate the command of mathematics as a both a general form of cultural capital and as the content of specific gatekeeper qualifications. Although this finding does not preclude the probable influences of other goals and roles, this role appears to both predicate and pervade the decision making process as described in every one of the interviews conducted. Beyond the explicit reflections on this role in the interviews, it is further suggestive that whilst the interviews do detail a number of motives why someone might want to learn mathematics, when A, D, F and G discuss being able to help their children they do not connect this desire to these other motives; it could be argued from both this and the corresponding questionnaire data that the desire to circumvent the social and political disadvantages of poor numeracy (and perhaps prevent circumstances repeating themselves) is more active in the decision making process than the desire to inculcate numeracy-based skills or facilities.

3.5.2 The Role of the Teacher and the Issue of Fault

The figure of the mathematics teacher was afforded massive weight by many of the interviewed learners. In almost all of the interviews the adult education teacher was afforded praise for helping the learner achieve and develop in confidence; conversely sometimes school teachers appeared to be utilised by the interviewees as embodiments and agents of prior negative experiences with mathematics.

The most striking case of this, and perhaps the most unfortunate turn of events, occurs in the account of participant A. In the first three years of secondary school she had a female teacher who “used to explain everything from scratch… from A to B.” However, this situation changed in the fourth year:

*A: Yeah, and then when I had Mr. ***** for Year 10 and Year 11, he would just explain the work for five seconds and he’d just go out. He would have a couple of fags, come back and he would have a coffee, and he used to really, really smell of fags, and we used to like think: you know, hold on, he hasn’t explained the work properly, what’s going on? And I think that’s what happened, and I just totally failed on maths. Then I thought, you know what, I need to do something in the future, so after I left school, I went to college, and I did maths there, and I had the same teacher again! Going back into college! Because he got sacked at school…*

A goes on to describe how she failed her college course, ostensibly since her teacher was awarding ‘U’ grades to all of her assignments with no feedback or notes for improvement. Fortunately, after some time in employment, she returned to mathematics again and had a more positive experience.

Participant G also recounted that poor teaching had demotivated her:

G: I think I always found it difficult, and I can remember when I was small, I mean very small, infant school, probably five or six, we were taught by nuns, and really the only way they could get through to you was humiliation, and they used to pull you up in the class and basically tell everybody how stupid you were. And I can remember my whole maths book just being crossed out in front of a whole class of kids. And I know that’s ridiculous, and it’s years and years ago, but those sort of things you remember and I think you carry those bad experiences with you, so if you’re told that you’re stupid about something, you just think, ‘well, I don’t really want to seem like I’m stupid’, so you stop making a bit of an effort, don’t you?

These accounts form a stark contrast to the majority of the comments offered about the participants’ current teachers, for instance:

B: Oh, fantastic. They’re absolutely fantastic, supportive teachers – they’re really, really good. And they didn’t give up on me.

The participants tended to focus on two key features: their new teachers’ capacities for explanation (see section 3.5.3) and their approachable, relaxed style. Both participant A and participant C noted that the insistence on titles had been dropped by staff:

*C: It was far more informal – there was no sort of, 'yes sir, no sir, three bags full sir', you know, if I had a question I could ask *****. It was far more informal, almost on a sort of friendly level – you know, just a friend who could do maths, whereas before it was sort of, you know, Mr. Such-a-body…*

D: I had this vision of it being more like she'd tell you something, then you'd go off and learn it, and then you'd have to get it right this week, and then you'd do this then… blah blah blah. But it wasn't like that, you got in, and it was so relaxed, and funny, and she was like, 'if you don't understand, I'll explain it this way.' And she'd stand there, wouldn't she, and she'd explain it in hundreds of different ways until it clicked. And then she'd be, 'well, there you go, see.' And 'Ha! I understand it now!'

*E: *****'s lovely. You know – she's the sort of person that will sit… and if you don't understand, she'll sit with you, and talk to you until you do understand…*

The comment from F that her teacher was "friendly, non-judgemental and competent" was similarly typical of the majority of the responses. This is an encouraging finding, albeit not one which is generalisable at this stage. A minority of comments were less positive; G had worked with two teachers, and said of one "he was a nice guy, but he was a maths teacher… maths teachers seem to always assume that your students know exactly what they're talking about." Equally, H was critical of her teacher's expertise:

H: We were correcting her mistakes, and she'd sit and set the work for us, and we'd finish before she'd finished explaining to the rest of the class, and that was really, really frustrating.

A related feature of the interviews was the ways in which some of the prodigals located fault in their educational biographies. As discussed above, A firmly blamed one of her school teachers for the fact that she had not previously qualified in mathematics. Some of her account might be understood as hinting at a more complex picture of pupil behaviour and learning; for instance, she described her class as “a fun-loving and a bubbly group… we got along with everyone, and we just didn’t want to listen to our teacher, because he used to explain the work for five seconds, then he used to be out again.” Regardless, A was resolute about the allocation of blame:

A: And when you’re doing it now, it’s like, “why didn’t I do it then?” and “why didn’t I concentrate then?” but obviously it’s not my fault.

Other interviewees recognised that their own behaviour may not have been fully conducive to learning, but despite acknowledging these faults they stopped short of accepting liability. Participant B reported that she had not asked for help from her teacher at school, but rationalised this as a consequence of peer pressure. Even C, who at first appeared to accept a measure of blame when he said “I think my attitude had a lot to do with it”, reasoned away his previous lack of motivation; after mentioning his partner’s son, he commented that:

C: Maths is one of those subjects as well, I suppose, a bit like History and Geography, it’s just not cool, is it? (Laughs.) You know, I mean, it’s not as cool as Woodwork and Science, where you can blow things up – it’s boring.

He then changed his opinion in light of his recent experiences, generating some discursive inconsistency:

C: Well, that's the way it seems, I mean, I thoroughly enjoyed going back and learning maths again. I mean that's why I said to you when you came and gave us the sheets about the idea of darts – I think playing darts in a classroom is a brilliant idea.

Although these excerpts are themselves valid and valuable features of the participants' accounts, it is should be recognised that the processes of fault finding could be prompting the narratives in wider ways. Reluctance to blame oneself for previous failings could turn the learners' foci outwards, inculcating or even imposing a sense of direction and improved circumstance. In some cases this might work to the advantage of this research, as participants might have thus forced themselves to rationalise why one teacher had been more successful than another and begun to consider pedagogical and philosophical aspects for themselves prior to the interviews; however this practice may further have inflated or distorted the participants' recollections.

The evidence of fault finding processes presented above also reinforces arguments of significance; it can be inferred that the participants' opinions of learning mathematics must be such that these processes are worthwhile or even psychologically necessary. This speaks in a broad sense to the combined import of the roles and goals of mathematics education.

3.5.3 Explanation, Context and the Nature of Mathematics

The comments included in the previous section demonstrated that the participants valued their teachers' ability to explain mathematics in a way that they felt they could understand. A significant component of this which the interviewees identified would appear to be the relating of mathematics to 'real life', as many of the participants praised their teacher's use of context and relatable examples. This is perhaps one of the most transparent instances where there has been a shift in the balance of goals and roles of mathematics, with the goal of establishing an individually relevant numeracy moving towards the foreground. Two examples are offered here:

C: There's still things I can't do, and don't understand, but in general I'm a lot happier… for instance, the course is sort of designed around real life, so if I went into a shop and it said that there was seventy-five percent off, I'm now able to stand there and work out how much I am actually saving. So yeah, there are lots of situations in life where I am now using number, where, I feel a lot happier… yeah, definitely.

E: Especially when I was doing the course, I was constantly thinking of things in the world, and sort of adding things, and trying to fit them into things that we had learnt in the class. So she was really making me expand on what I was learning, and giving me confidence in that as well.

Some comments suggested that 'real-life' was appropriated not only for motivation, but also as a source of visual imagery. For instance, D recalled a lesson involving fractions:

D: No, she stood there, and 'cause we're all adults, bless her, she'd describe everything in terms that we'd understand. So she'd say, 'well, when you're out, if you've got this bottle of wine and this bottle of wine, and you put them together, well what do you get?' And it all sort of clicked, and fell into place! (Laughs.)

Utility was also linked to difficulties with memorisation:

B: I think that's another thing why I forgot a lot of maths (at school)*, because I thought, 'I don't need it, so why do I need to do it?*

Strikingly, participant G had moved beyond the simple transfer of classroom mathematics routines to contexts, and had begun to see through some of the limits of classroom mathematics in order to develop a realistic and enabling perspective on the application of mathematics:

G: If somebody asks you to do something at work, you'd think, 'well I don't know, but I know what pi is, and I know how to work out the circumference of a circle', so you put each bit together, but nobody would say, 'right, I, I want to know in five minutes'. So… you know, I think as a grown up you realise that things are different in the real world to, learning in school.

From the context of the phrase it is fair to infer that these 'things' include mathematics, and so G is explicitly noting here that she has come to realise mathematics is something different to what she thought it was at school. Later on in the interview, she outlined her opinion that recasting mathematics as a toolkit would help motivate pupils:

G: It should be made to seem… interesting. You know, this is your problem, we're going to give you the tools to work out that problem and you're going to find the answer to it. I mean, it's a really good thing, isn't it, but it's not shown to you like that, you know, you are going to be able to figure out the answer to this problem. You're not going to have to guess it, there's a way you can do it.

Finally in this section it is interesting to note that comments on this theme were offered by learners on both numeracy and GCSE level courses; despite the different balances of intrinsic and extrinsic motivations behind the decision noted in section 3.4.5 both numeracy and GCSE level participants seemed to be more familiar with using and applying mathematics as a result of their adult studies.

3.5.4 Fear and Confidence

The interviews often involved learners' emotional responses to learning mathematics. Although any attempt at a unified summary of the participants' related experiences would be misleadingly simplistic, it is fair to say that most participants indicated a gradual transition from fear to confidence. The narrative presentations frequently connected this improvement with the application of mathematics in the real world, and the quotes in the previous section offer many discursive markers of a growing assurance. This connection was often quite explicit:

I: Something you said in your questionnaire is you had to overcome the fear of maths… What do you mean by 'fear of maths'?

G: You know, somebody asks you a question at work, I need to take off 10%, or I need to take off 15%, or 25%, or… and I was sitting there thinking, 'God, please don't ask me that question.' I wouldn't even attempt it, I wouldn't, I'd feel stupid and ridiculous if someone asked me something about maths, and I hated that feeling, really…and that situation has actually cropped up recently, and although I couldn't remember the exact thing he was asking me, I went and I sorted it out, and I reminded myself of how that formula worked.

Although they may have not returned to learning mathematics with the intention of challenging their mathematical self-image, many found themselves reassessing their mathematical abilities:

E: Before I think I looked at it and thought, 'I can't do that', but I feel I, I can do it, and I'm willing to try as well, and I don't want to just switch off and say 'no'. I'm willing to try.

C: You know, I did my first class, and I just felt ten feet tall. I thought, 'I can do this, I can go back to school and learn!' You know, I'm not past it, at twenty-nine years old, I'm not incapable, and after my first maths class it was just ten-fold, because I couldn't do maths. And all of a sudden I sat down, I felt like I'd learnt something, and… you know, it was fantastic all of a sudden – this thing I couldn't do, it was like, ooh, well maybe I can do this actually…doing those two courses (Numeracy and Literacy) *inspired me to go on and do the 'access to higher education'…*

A: Yeah, I do feel different, I feel more confident with giving someone change without using a calculator thing and going on the till– obviously, you've got to go on the till and put the transactions through, but now I could just pick up the change if someone's given me a tenner and I know what to give back to them…

Such accounts are positive comments on adult education in and of themselves: for instance, D moved from 'not being comfortable' with mathematics to 'adoring' it in the space of her GCSE course; next year she is beginning A-Level Mathematics.

It is clear that these participants' views of themselves as potential users of mathematics have improved, but from the structure and content of their narratives it is also possible to argue that this improvement is part of a reflexive repositioning of the nature of mathematics itself. There is similar evidence that in instances where the learner has not been able to recast the mathematics, their confidence has failed to develop. Participant G, who elsewhere claimed to have overcome a 'fear of maths' and who demonstrated a considered and enabling approach to the application of mathematics had one outstanding concern:

G: That's the one thing I really struggle with, algebra... I suppose from a scientific point of view, or those people that need it... I'm sure that obviously it's a really useful tool, but... you know, 'a' plus 'b', apples plus bananas equals 'ab', you know, they're apples and they're bananas to me... I still see it as pointless.

This is quite suggestive, and indeed much of the interview with participant G appeared to demonstrate tension between two views about mathematics. This was clear from the start of the interview which contained a suggestive slip with the definite article:

G: I think it's the – a really difficult subject, and I think it's something that lots of people aren't very good at. I think you're either really good at maths, and like it, or you really can't stand it – it's a bit like Marmite, I think... I don't know, I do like maths, I like the ways things figure out – I find it hard still, but it's an answer to a question that you're asking... it is as it is... it's black and white, isn't it, maths?

As we have seen, G went some way towards resolving this tension by differentiating between 'useful' and 'pointless' mathematics. Participant B worked in a primary school and made a similar distinction, referring to “this kind of maths”. Whilst it is necessary to consider that these divisions may derive from the different cognitive demands made by areas of the curriculum such as algebra, it is plausible that this demarcation is, at least in part, a psychological construct, deployed to reconcile a learner’s recent successes with inferences about, or difficulties with, mathematics. In this way such partitioning could be related to the discourses surrounding the purposes of mathematics education.

Finally with regard to the emotional responses it was interesting to note, though not surprising in light of the questionnaire findings, that few participants expressed any fear of examinations. Many recognised that assessments had a valuable place in the learning experience, and some, such as E, recognised some strengths of the modular system: “you complete something and you’ve got that instant ‘well done’… you think, ‘OK, I’ve done really well, so let’s push a bit further.’”

3.5.5 Ability Grouping and School Organisation

The issue of setting first arose in the responses to the questionnaire items on test and assessment, and the interviewees similarly volunteered their views on how setting had affected motivation and achievement. Many of the comments were general, commenting on group size or atmosphere, but some of the participants specifically identified organisational factors as having steered their mathematical trajectories. For example, participant G:

G: I was in the low, foundation (set)… you know, ‘F’ student, just hated it really. (Laughs.)

I: You hated being in that set?

G: Yeah, because I think the highest I could get was a 'D' anyway, and I didn't even get that, I got an 'F', so, it was almost pointless really. I don't know why I didn't like it, I don't know… I think because I couldn't do it I just lost interest.

C claimed to have become demotivated in a similar way:

C: Then obviously we got streamlined into sets. I was in the bottom set and then – that was sort of it then, I was quite happy to sit there and happy with the notion that I couldn't do maths and that was that.

D was in a "horrible" middle ability set and related how setting had encouraged an unhealthy atmosphere of competition:

D: It was like they were constantly pushing you. And the way they'd split the classes up, so you had bottom maths, middle maths, higher maths, it was like – the person in higher maths was (?), 'oh yeah, but I'm better at maths than you, I'm in a higher group than you', and all that sort of stuff, and we never had that in college, because you're all in the same group.

Conversely, E had a negative experience when she was placed in a top set:

E: I was put in the wrong group really, because I was put in the top group, and I had no idea what he (the teacher) was on about most of the time. So I switched off, really. I think if I'd started in a lower group I would have found my feet and then maybe been able to progress up. But at the top group there was all the really bright kids, and I had no idea what I was doing.

There was some appreciation of the reasons behind setting: G talked about not wanting to 'hold back' the more able, and the discussion with H mentioned in section 3.5.2 implied that she was frustrated by the fact she was in an adult class with a wide range of learners. Nonetheless, the majority of the participants demonstrated unhappiness at the way they had been placed in sets, and many attributed some of their failings in mathematics to this practice.

There are strong discursive markers in these quotes of the participants' views about the purposes behind learning mathematics. The most telling of these indicators is arguably G's comment that being in a group that could at most attain a 'D' grade at examination rendered learning mathematics "almost pointless"; this phrasing openly declares the primacy for this learner of the role of mathematics as a gatekeeper qualification.

Others of the comments hint at the related conceptions that mathematical ability is innate, and that it serves as an indicator of intelligence; participant C's wording has a tenor of finality as she resigns, however happily, to "the notion that I couldn't do maths and that was that." This model of mathematical intelligence can also be read into G's concern not to 'hold back' the more able and the competitive aspect of D's account. Indeed, D recounted that mathematical ability had been presented at school as largely fixed: "Well, if you get this, you get this. And if you can't do this, you can't do this." In summary, it could be argued that for many (if not all) of the participants, their school experiences had engendered a robust sense of the role of mathematics as a standard gauge of fixed intelligence, and that this sense persisted despite changes in the organisational structures which had originally acted as strong and influential supports for this position.

3.6 Discussion

The results and comments above have addressed each of the three localised research questions, providing new evidence about the demographic make-up of two subsections of the adult learner population, the motives behind the decision to return to mathematics, and how prodigal learners' experience of learning mathematics as an adult compares to and contrasts with their experience of learning mathematics at school. This section will briefly summarise how this evidence further informs the two global research questions; a further synoptic discussion is presented in chapter six.

3.6.1 Global Research Question One

- How do the experiences and mathematical trajectories of learners reflect the competing goals and roles of mathematics education?

The data presented above conclusively demonstrates that the recent mathematical trajectories of these learners have been predominantly influenced by the social and political roles of mathematics. Both the questionnaire data in section 3.4.5 and the interview data in section 3.5.1 demonstrate that GCSE level learners were principally motivated by a need to gain this qualification to proceed in further education and/or employment; the educational histories reported in section 3.4.3 further support this conclusion by pointing towards the particular worth of higher grades. Whilst the numeracy learners demonstrated a wider range of responses, such that some of the epistemic goals described in chapter one might be inferred from the respective questionnaire data, the data admits the argument that many of these motives, such as the desire to help children, were still fundamentally consequent from the role of mathematics as cultural capital.

The experiences of the prodigal learners were however influenced by a more involved blend of goals and roles. The narratives arising from the interviews and the results of the final section of the questionnaire show that the prodigals' experiences of learning mathematics as an adult were markedly different from their school experiences in ways that closely resonated with a shift in how the learning of mathematics might be understood. Most notably the frequently commended use of context and everyday situations in the adult classroom, explored in section 3.5.3, echoes the goals of establishing an everyday numeracy and preparing learners to use and apply mathematics in the workplace. There was also some evidence in the interviews that success with mathematics had promoted both further interest in the subject, and an appreciation of how mathematics can be utilised as a problem-solving tool.

To this end, instead of asking what motivated the prodigals to return to mathematics, it may have been more salient to have asked "what motivates the prodigals to learn mathematics at different stages of their course of study?" There was substantial indication in the data that goals which had previously been secondary to or unacknowledged by the participants had played a valuable part in sustaining their interest and serving to motivate continued study. Similarly, whilst none of the learners reported that their primary reason for studying was to improve their confidence, the results of section 3.5.4 show that many of the learners both recognised and valued how their academic self-image had grown with respect to mathematics. In conclusion, it could be argued that the experiences of the prodigals often bring more of the goals and roles of mathematics into closer alignment, and that many potentially finish courses not only knowing that mathematics is useful, but also appreciating more fully why this is the case.

3.6.2 Global Research Question Two

- How do learners navigate and make sense of competing or co-existing goals and roles of mathematics education? In particular, how do they make sense of their own mathematical purpose?

The extant research literature often extols the importance of the role of the teacher in adult education. This standing is also powerfully evident in both the questionnaire and interview data, and it is thus apparent that the adult education teacher at least mediates, and likely instigates, shifts in learners' understanding of the goals and roles of mathematics education. This process is partially enacted through pedagogic choices such as the use of context already discussed above. However, there is also a notable shift in the locus of control through changes such as the removal of formal setting and the repositioning of the teacher as another adult, who might even be addressed by their first name. It could be argued that this shift encourages the learners to see the teacher less as part of an organisational hierarchy and more as a relatable archetype of mathematical behaviour and activity. Further it can be suggested that learners in part navigate and make sense of the competing goals and roles of mathematics education by modelling their behaviour after that of their teacher.

Whilst the interview data demonstrates that the participating learners had typically developed a greater awareness of the epistemic aims of mathematics, there is also evidence that at least some had struggled to accommodate these shifts. Certain of the interviews contain discursive inconsistencies, or attempts to rationalise previously held views of mathematics with current opinions by splitting mathematics by content or level. This is a particularly concerning finding. It suggests that even when changes in educational context bring goals and roles further into alignment, previous experiences and emotional associations arising from these experiences can undermine positive changes and persist in steering learners' understanding of their own mathematical purpose. This speaks to wider concerns in mathematics education, by stressing the importance of affect at all stages of mathematical learning.

3.7 Summary of Emergent Categories

Some of the categories developed in this analysis, notably those pertaining specifically to the prodigals' decisions to return to the formal learning of mathematics, did not have an immediate bearing outside of this chapter. However, many of the emergent categories used in the grounded theory analysis of the data had a wider concern and were carried through into the following chapters. Chiefly, the following categories were employed in some form at this stage of the research:

- the import of mathematics as a gatekeeper subject and as cultural capital
- explanations, contexts and connecting mathematical learning to the 'real-world'
- ability grouping and competition
- emotional responses to success, difficulty and failure in mathematics
- teachers as model practitioners of mathematics and the import of the teacher-learner relationship

These categories then contributed to the subsequent research as detailed in figure 2.1. Other data, notably the interview comments about dividing up mathematics in section 3.5.4, and comments about the place of memory in learning mathematics, remained coded and were later assimilated into categories, after resonances and similarities between researched groups of learners were observed. This process is detailed in the following two chapters.

CHAPTER FOUR: EXPLORING THE DECISIONS AND EXPERIENCES OF UNDERGRADUATES CHOOSING TO LEAVE MATHEMATICS BEHIND AFTER GRADUATION

4.0 Introduction

The preceding chapters have argued for and illustrated the place of mathematics qualifications, particularly GCSE mathematics, as cultural capital in contemporary English society. Mathematics holds an analogous standing in higher education: a mathematics degree is well respected, has a high earning premium, and can facilitate entry into a number of exclusive career paths. Access to this qualification is limited, but for pupils who have attained sufficiently highly in mathematics at school, a mathematics degree is widely regarded as a secure, profitable and valued choice.

Against this background, considering the decisions and experiences of undergraduates who elect to move away from mathematics after graduating may provide some important indications in the inquiry into the questions which underpin this research. Learners in this position are opting to leave behind a subject that they have chosen to study during at least two stages of post-compulsory education, and in which they have attained highly; they are thus greatly changing the course of their mathematical trajectories. This thesis has argued that learners who have intentionally altered their mathematical trajectories make more obvious the competition between the goals and roles of mathematics, and so this second subgroup of learners is apposite for analysis.

Whilst undertaking my research programme I had the privilege of delivering a mathematics education module to a mixed group of second- and third-year mathematics undergraduates. In each cohort that I taught there were a significant number of students who felt disaffected, and who openly admitted that they had opted into the education module as a consequence of a growing disinclination toward mathematics. Informal discussions with these students had convinced me that these students represented a socially significant proportion of their peers, and so I took advantage of the opening to construct an opportunity sample that would usefully complement and contrast with the other groups considered in this thesis. This chapter presents the mathematical biographies of four of these learners, and considers how their decisions and experiences might illuminate the global research questions of this thesis.

4.0.1 Localising the Research Questions

Section 1.3 stated the global research questions as follows:

- How do the experiences and mathematical trajectories of learners reflect the competing goals and roles of mathematics education?

- How do learners navigate and make sense of competing or co-existing goals and roles of mathematics education? In particular, how do they make sense of their own mathematical purpose?

Whilst the undergraduate learners were selected via a qualifying incident, as the prodigal learners of chapter three had been, there were significantly fewer of the undergraduates. The limited size of the opportunity sample was therefore exploited to facilitate research which included a fuller mathematical history of the participants, so as to place the decision to move away from mathematics in context. In light of this, the first local research question was phrased as an adaptation of the first global research question:

- **How do the experiences and mathematical trajectories of these learners, particularly their decision to leave mathematics behind after graduating, reflect the competing goals and roles of mathematics education?**

Whilst a comparable adaptation of the second global research question could be sustained, this might not have properly recognised the emergent grounded theory categories that had been developed in the previous chapter and listed in section 3.7.1. To this end, the second local research question was addressed through the construction of two local research questions which more fully permitted further illumination of these categories:

- **What changes and developments have these learners recognised in the different stages of their mathematical learning? In what ways do these reflect changes in competition and co-operation between the goals and roles of mathematics education?**

- **How have these learners responded to, and made sense of, these observed changes and developments?**

In this way, these three localised research questions were not only able to add to the global exposition of this thesis, but were also more closely consonant with, and developed to be mindful of, the preceding research. The full methodology is offered in section 4.3 and the narratives of the undergraduates follow in section

4.4; a discussion of these narratives and how they contribute to the global research questions then follows in section 4.5.

4.1 Literature Review

This section summarises the portions of the literature review which specifically support this particular component of the thesis research, namely those concerned with the value of a mathematics degree, pedagogy in undergraduate mathematics teaching, and undergraduates who leave mathematics and related disciplines behind.

The paucity of specific extant research in this field, and the related lack of a consistent lexis of key words made systematic searching methods problematic. Instead key texts and references were used as a starting point, from which references and key researchers in the field were identified and integrated into the literature search. As with section 3.1, a sufficient degree of saturation was assumed when all specialist terms and theoretical concepts were understood, and the readings seen as most central to the research questions were considered to form a coherent whole. A further check of sufficiency was garnered through the course of peer-review; during the process that led to the publication of this chapter as Ward-Penny, Johnston-Wilder and Lee (2011), contemporary researchers in related fields remarked on the theoretical framework and offered a small number of extra items they considered to be germane.

4.1.1 The Value of a Mathematics Degree

Post-compulsory study of mathematics has the potential to stimulate a number of concrete benefits in contemporary English society. Dolton and Vignoles (2002) confirmed the particular economic return of A-level mathematics by demonstrating that workers with A-level mathematics earned between seven and ten per cent more than those with similar educations, even when controlling for ability. This economic return is even more pronounced in the case of a mathematics degree. Whilst almost all degrees have an expected economic premium, Walker and Zhu (2001) working with data from the 1990s found that males with a mathematics degree earned 26% more than workers with only A-level mathematics, and that this statistic rose to 39% for females. The only higher premiums for males were associated with health, law and economics degrees, although these only involved a slightly higher premium of 27%; for females the research only found higher premiums in health (44%), law (44%) and architecture (41%). More recent research from Universities UK (2007), using pooled labour force data from 2000-2005, calculated the gross additional earnings of a mathematics or computer science graduate at £241,749; their categorisation resulted in higher figures only for graduates in engineering or medicine. Whilst single summary statistics of this nature hide significant variation, and the use of different categories in these studies limits comparisons (for instance the latter report includes neither law nor economics as a discrete category of degree), research into the earnings premium of a mathematics degree consistently and explicitly speaks to the favourable economic standing of mathematics as a degree subject and its corresponding financial reward.

These fiscal gains can be understood in part by considering the employment opportunities that a mathematics degree facilitates and is associated with. According to Critchlow (2012), the modal class of employment taken up by students who graduated with a mathematics degree in 2011 was “Business and

Financial Professionals and Associate Professionals". The 39.9% of former students who began employment in this sector included actuaries, financial analysts and chartered accountants (p.22). Whilst a mathematics degree might not act as a gatekeeper in as strict a sense as the GCSE 'C' grade discussed in the previous chapters, it does enable and expedite entry into many of the higher paid professions in contemporary England.

The economic and employment benefits associated with a mathematics degree are already enough to substantiate the position of a mathematics degree as cultural capital, but mathematics and mathematics-related degrees also possess value in other, less visible ways. The symbolic capital of mathematics as a discipline continues to ensure that mathematics and related degrees are respected and largely stable (for example within Vorderman et al. 2011); the standing of the mathematics degree in higher education has arguably changed little over the last twenty years, despite substantial moves such as the expansion of higher education under new Labour, the subsequent debate regarding 'mickey mouse' degrees and the introduction of tuition fees (Brown 2011). If at all, it could be reasoned that the growing prominence of discourses promoting the need for science, technology, engineering and mathematics (or STEM) graduates (for instance Roberts 2002) has strengthened the perceived character and worth of the mathematics degree, and upheld it as a higher education qualification which is relevant to emerging technological possibilities without being limited by them or at risk of becoming outdated. In these interlinked ways a mathematics degree is a substantial and robust piece of cultural capital in contemporary English society which adds value in terms of finance, prospects, and social standing.

4.1.2 Pedagogy, Identity and Undergraduate Mathematics

Within recent educational research there has been a growing interest in the possible implications of pedagogic styles within higher education. It has been widely noted that pedagogy has an impact on learner's affective responses to mathematics in secondary school (for instance Nardi and Steward 2003) and this line of research considers how this interplay might continue into tertiary education.

Perhaps most notably in respect to this section of the thesis, Solomon (2007a) considers the experiences of twelve first-year undergraduate mathematics students at an English university and argues that whilst some students were heavily aligned with the dominant community of practice, others had positioned themselves on the fringes of legitimate practice and developed a marginalised identity. She offers that key influences on the students' positioning are fixed ability beliefs (after Dweck 2000), and institutional structures and practices, including pedagogy. Later research (Solomon, Lawson and Croft 2011) has gone on to argue that women are at particular risk of developing a 'fragile identity'.

A supporting contrast to such criticisms of dominant pedagogies is offered by Povey and Angier (2004) who detail the experience of undergraduates at a different English university which accepts learners with a weaker entry profile, and which actively strives to engender a social, collaborative approach in its undergraduate mathematics program. Povey and Angier claim significant levels of success, both in terms of attainment and affect, and maintain that "offering a different pedagogy, one that values agency and authorship, one that places the learning community as central, has enabled some failing and initially weak students to construct authoritative mathematical identities" (p.63). Consonant support can also be marshalled from research into the American "Emerging Scholars" programme (for example Duncan and Dick 2000) which similarly involves collaborative pedagogy and claims increased levels of motivation and achievement for many students.

4.1.3 On Leaving STEM Disciplines

Section 4.1.1 has already noted the existence of STEM-focused agendas which declare the need for a greater mathematical and technical literacy in the national workforce. However, concerns have emerged in recent educational research that the transitions and pathways implicit in such discourses are idealised, and that any such deficit in the workforce might not be solved simply by increasing the number of STEM graduates. This more nuanced consideration of the nature of the 'STEM problem' has begun to emerge in some recent industry-led reports (for instance Mellors-Bourne et al. 2011).

Educational research into 'failure' in mathematics at undergraduate level has likewise developed from primarily considering attrition rates and failure to graduate (for instance Macrae, Brown, Bartholomew and Rodd 2003) to also noting that a significant number of learners are becoming disaffected and leaving mathematics behind after graduating (for example within Wiliam 2005). The choices of such students speak to the wider goals of this research; these learners, despite having previously been construed as part of a mathematical elite, are making deliberate decisions to alter their mathematical trajectories.

At present, there is a paucity of specific studies in this area. It is also challenging to draw exact international comparisons; for instance whilst noted American research such as Seymour and Hewitt (1997) conveys the intentions of students moving away from STEM disciplines, the process of ‘switching majors’ does not offer an exact parallel to leaving mathematics behind after completing an English undergraduate degree. However, the research that exists appears to be indicative of a significant concern. Perhaps most specifically Burton (2004, pp.4-5) reports on a small-scale study wherein 54 per cent of the female and 25 per cent of the male undergraduates interviewed evinced a resolution to move, after graduating, to a career that did not involve mathematics.

To this end, much of the educational research that informs the research within this chapter concerns the more general perspectives of students as they transition to and negotiate the practice of undergraduate mathematics. This is briefly presented in the theoretical framework which follows.

4.2 Theoretical Framework

This section offers a brief additional comment on the theoretical framework which is specifically relevant for this section of the thesis research. As such it draws on the discussions of section 2.3, as well as the preceding literature review, and outlines how some of the key elements of the wider theoretical framework have been understood in the context of this particular group of learners.

4.2.1 Undergraduate Mathematics as a Distinct Community of Practice

Even as all mathematical learning can be construed as taking place within a ‘community of practice’ (Lave and Wenger 1991), this theoretical concept can be readily and constructively mapped onto the practice of university mathematics (for example Solomon 2007a). Upon arriving at university, undergraduate students are inducted into a community with a defined hierarchy and sense of shared enterprise. Further, the ways in which undergraduate mathematics programmes typically establish the approved syntax and modes of ‘professional’ mathematics, particularly in foregrounding proof, readily institute undergraduate mathematics as ‘legitimate peripheral participation’.

The distinctiveness of this community of practice is well documented and recognised internationally; for instance Luk (2005) holds that whilst the gap between school and university mathematics can take different forms, its existence is self-evident. Posited and observed difficulties include novel forms of cognitive demand (for instance Tall 1994), a qualitative shift in the preferred type of understanding (Skemp 1976) as well as changes in pedagogy and course delivery.

To this end this thesis recognises the nature of university mathematics as a community of practice, as well as the theoretical framework offered by Solomon (2007a) that disaffection in some undergraduate mathematicians might be understood as a perception of oneself outside of legitimate peripheral participation, and that such learners “are aligned with mathematical procedures but do not contribute to them” (p.79). In this way it also holds that the notion of identity is salient in understanding the narratives of these learners.

4.2.2 Narratives, Mathematical Identities and Figured Worlds

As in the preceding chapters, this thesis continues to hold that identity is neither wholly essential nor wholly intrapsychic, rather that identities are formed and reformed in the light of experiences in the affective domain. The students’ mathematical identities (Boaler and Greeno 2000; Black, Mendick and Solomon 2009) demonstrate how the students position themselves with respect to the community of practice that is university mathematics, and thus report on the students' self-efficacy (Bandura 1995). The term agentic identity is more specifically used in this chapter, to encapsulate the aspects of students' internally conceptualised notions of self which relate to their capacity to act and influence within pertinent figured worlds (Holland et al. 1998).

The use of this position informs the methodology for this component of the thesis, by rejecting the notion that identity is extra-discursive. Instead, as identity building is a communicative practice (Sfard and Prusak 2005) the narratives themselves are paramount, offering insights into the identity building processes of the participants; this understanding is consistent with the use of interviews as a methodological tool.

4.3 Methodology

The localised research questions of this component of the thesis were worded in section 4.0.1 as follows:

- **How do the experiences and mathematical trajectories of these learners, particularly their decision to leave mathematics behind after graduating, reflect the competing goals and roles of mathematics education?**

- **What changes and developments have these learners recognised in the different stages of their mathematical learning? In what ways do these reflect changes in competition and co-operation between the goals and roles of mathematics education?**

- **How have these learners responded to, and made sense of, these observed changes and developments?**

These questions, the small size of the opportunity sample, and the centrality of the learners' own narrative as established in the theoretical framework together determined the selection of the interview as a research tool; as Seidman (2006) argues, "if the researcher's goal… is to understand the meaning people involved in education make of their experience, then interviewing provides a necessary, if not always completely sufficient, avenue of enquiry" (p. 11).

4.3.1 The Opportunity Sample

As outlined in section 4.0, the opportunity sample was composed of volunteers who were taking a mathematics education module as part of their undergraduate mathematics degree. The purpose and form of this research were briefly described to the undergraduates towards the end of their course, and 13 students volunteered to take part in the research.

The prime ethical concern in this research arose from my personal dual role as researcher and course tutor; whilst both the content and direction of an interview are inescapably influenced by the interviewer, it is possible that if I were to conduct the interviews myself the participants might have been steered towards replicating discussions from the lecture course, or have felt pressured to offer the 'correct' response to a figure with some authority over their grades. To this end I recruited two colleagues each of whom interviewed half the sample. They were willing to act as co-researchers as they had some interest in the outcomes from their own research perspective. Hence whilst I, as lead researcher, organised and co-ordinated the sessions I was not present at any of the interviews.

A selection of five students emerged through purposive sampling and limits on availability, both on the part of the co-researchers and the participants; this was reduced to four when one student repeatedly had practical problems with transport on the day. Although this was smaller than originally intended, after a review of the quality and nature of the data, it was determined that a second call for participants was not necessary.

4.3.2 Interview Design, Application and Analysis

The interviews were semi-structured. The absence of a single rigid structure was intended to allow the participants to express their narratives in their own ways, sharing discursive markers in both the form and content of their telling; conversely, the presence of some structure encouraged a greater degree of consistency between the interviewing co-researchers and facilitated comparisons and inquiry at the analysis stage. Each interview began with a short introduction which was intended to set the tone of the discussion and make clear its purpose:

The aim of this project is to listen to your stories about learning mathematics at school and at university, and to talk about how mathematics may or may not feature in what you choose to do next. We want to hear what you have to say about learning mathematics, what helped you to learn and what did not help you. We have some questions that we would like answered but what is most important is that we hear your story.

The interviews were conducted using a prompt sheet of six questions to ensure similar coverage. These were principally worded to warrant coverage of the local research questions, although the fifth of these was included in part to recognise the interests of the co-researchers. Whilst the questions were ordered to support a chronological recounting of each participant's mathematical history, the interviewers were free to reword or reorder the questions in response to their sense of each participant's emerging narrative:

- *Tell me about your experiences of mathematics at school.*
- *What made you decide to do a mathematics degree?*
- *Tell me about your experience of learning mathematics at university.*
- *Was learning mathematics at university different from learning mathematics at school?*
- *Have you developed or used any particular strategies or approaches to help you make progress with mathematics at university?*
- *How do you feel about mathematics now?*

Sub-questions could be added if this was deemed necessary at the interviewer's discretion. The interviews typically took between half an hour and an hour. After transcription the interview data was coded and analysed in the same manner described in section 3.3.3.

4.3.3 Ethics

This research was designed and carried out in line with university guidelines regarding ethical research (the relevant ethics form is reproduced in Appendix C). Measures were taken at each stage to involve, respect and protect the participants; as well as the use of two co-researchers as interviewers detailed above, participants were invited in an e-mail which made it clear that they could opt out at any stage. This section of the thesis research was carried out in a particularly transparent manner which recognised that the participants themselves had some interest in mathematics education as a field; in line with the democratising ethos of critical theory the students were invited to ask any questions they had about either the analysis or the research and publication process.

The particular nature of the sample challenges claims to full anonymity, particularly as it applies to the educational institution. Nevertheless personal anonymity was supported through the use of pseudonyms both in written summaries of the research and in the interview transcripts. The interviews were timed in such a way as to have the minimum impact on any of the participating undergraduates' examinations.

4.3.4 Validity and Reliability

A number of practical steps were taken in the design of this research to bolster the validity and reliability of the data. Principally, a semi-structured interview was chosen to try and hold validity and reliability in tension during the co-construction of the narratives. The imposition of structure was intended to limit interviewer bias and support consistency between the two interviewers, whilst the capacity for open-ended responses allowed the participants to demonstrate their unique perspective and thus supported content validity. The use of two co-researchers also supported the content validity of the findings. One co-researcher interviewed 'Cathy' and 'Mark' and the other interviewed 'Adam' and 'John'; the presence of resonances both between and within these pairings corroborates their actuality. Finally, both co-researchers were experienced interviewers with a conscious awareness of their own biases, and my position as lead researcher facilitated additional checks and comparisons.

At the beginning of the analysis stage all three researchers coded all of the data and these preliminary codes were cross-referenced and compared. The closeness of the three sets of annotations further supports the internal validity of the resulting concepts.

The sample size was unequivocally small, and thus the research reported in this chapter makes no claims of generalisability in and of itself. Indeed, the potential value of this sample was in part related to its uniqueness. The fact that these students had attended a series of lectures on theories and research regarding mathematical learning meant that they had considered their own mathematical learning in depth prior to the interview; this bolstered the scope for both discussion and precision in the generation of shared meanings. The context of the sample also facilitated an uncommon level of access. In this way this sample fits the purpose of grounded theory research, in as much as it does not seek to generalise but to look for features in the available data; despite its size this sample thus contributes to the validity and reliability of the global research of this thesis.

4.3.5 Researchers as Instruments

The reflexive practice which supported the critical approach of this chapter was both sustained and complicated through the use of two other researchers, as detailed in section 4.3.2. Whilst the categories used in the analysis stage were exposed and agreed by all three researchers, all three researchers had partialities which are recognised here.

My own personal experiences were perhaps most directly relevant in this setting; I had completed an undergraduate degree in a very similar context and, whilst I had not experienced the level of difficulty and disaffection reported by the participants, I was aware from my own experience of potentially salient topics such as the strategic use of memory to succeed in certain examinations. My exposure to the concerns of these learners through discussions which had taken place as part of my course also meant that I had to guard against an overly empathic perspective.

The two researchers who conducted the interviews had less immediate experience of learning undergraduate mathematics but had research interests regarding resilience in mathematical learning which were separate to this thesis (for details see Johnston-Wilder and Lee 2010). Although both were experienced interviewers, it is proper to recognise that this may have led to some researcher bias in the co-construction of the narratives.

4.3.6 A Note on the Representation of the Language used in Dialogue

The primacies of the interview as a methodological tool in this section, and of the narrative as a unit of analysis, both attach a greater import to speech disfluencies than was the case in chapter three. To this end quotes from the interviews are presented as they were transcribed. A comma and a dash represent shorter and longer pauses in speech respectively, whilst an ellipsis signifies a jump within the transcription.

4.4 The Stories of the Undergraduates

This section presents the results of the four interviews. Although the interview data was analysed thematically, each interview is first presented here as a whole to give a better impression of the shape of each learner's mathematical history.

4.4.1 John's Story

John was a third (final) year undergraduate taking a mathematics degree who had "always enjoyed doing maths" at school. He admitted that his self-identification as a talented mathematician had been based on, and reinforced by, attainment, and that he had related success to both absolute and relative measures of performance:

"…now I look back at it, the reason I enjoyed it was because I was able to do it. And maybe being better than other people made me want to keep on being better, which is why I kept on trying to do it… if we got set a challenge of one to ten questions, I just saw it as a challenge and I wanted to do them all… I liked getting it right, I liked beating other people."

John also appreciated that his "favourite teachers were always mathematicians or maths teachers… I presume that must have made, must have impacted me in some way." His attitude was that he "didn't decide to do maths, maths decided to sort of take me along with it… what I was going to do at university wasn't much of a choice, in my eyes, because it was always what I was good at and what I enjoyed." Thus at each stage of his school education John had 'dropped' his least favourite subjects until eventually John's study was centred on A-levels in mathematics and further mathematics; he felt with hindsight that this narrowing had not been prudent: “suddenly maths doesn’t seem so interesting… and I’m trying to do different things now.”

Mathematics at school for John had been about “yes, no, right and wrong”; perfection was not only possible, but preferred. He added that “I didn’t want to fail, ‘cause anything less than a hundred per cent was bad. Back then.” However, the nature of mathematics seemed to change once John reached university:

“I thought it would be like – I thought it would be a continuation of A-level, where you’d get, you’d get shown examples and you were given numbers. And you apply it… I didn’t think it would be anything like this at all… it’s totally, totally different field…”

“…the way I’ve always seen it is maths solves problems… whether that’s you count the number of beans, how many beans are there together… finding the gradient or find the co-efficient where something falls down a slope or something, I’ve always seen the point, the purpose to it.”

John’s narrative suggests a definite shift in his perception of both the nature of mathematical activity and legitimate participation; changes in his personal figured world of mathematics had thus impacted upon his identity as a mathematician. Perhaps in reaction to this, he goes on to argue that the new emphasis on proof weights cognitive skills which are of a lower order, and lead to less long-term benefit:

“I used to think it was solving problems… effectively solving problems in different ways. But the new maths that seems to be at university is learning things off by

heart, learning lots of lines off by heart…which isn't very useful any more… Because everything you do in maths you learn to forget."

John exemplified this by saying that he thought he would find it difficult to recall his first year mathematics work now, "because I learnt stuff to forget it a week later." This line of reasoning continued in a discussion about how he felt "you've got to play the system" by relying heavily on the short-term memory, that "rather than trying to actually understand it, sometimes it's just better to put stuff in your mind so that after – literally a week after the exam or the day after the exam it won't be there anymore." In his first exams, half-way through the first year he had tried learning and revising in the same way that he had done at school, but he had not done as well as he had hoped to. Thus at the end of the first year he changed his approach, and more successfully "played the system of how you get the marks." The frustrated tenor of John's comments could be understood as being indicative of a fundamental shift. At school John had affiliated purposeful mastery of mathematical techniques with success in the associated qualification, but now these two aims seemed to be in opposition. Interestingly, he still referred to developing understanding as "the right way" which hinted at a continued aspiration to mastery.

Within his interview, John recognised a number of differences between the pedagogic practices of his school and his university. In particular, at school he had "asked a lot of questions" and, identifying himself as part of a community of practice, had felt able to ask questions of both older pupils and teachers. Conversely, at university he had become frustrated and stopped asking questions.

He expressed this in terms which positioned himself outside of the community of practice:

"I sort of found that the people I was asking, the people I was asking the questions to, were on a different level to what my understanding was, so they were using terms and phrases which I just didn't – I couldn't relate to. Not because they were wrong, but because I was maybe on a different sort of level where – I've talked to a few friends at home and they say that the people who are best at explaining stuff are people with fewer letters at the end of their name. I think that's extremely true. So the people who've just done a degree are much, much better at explaining new terms, and are much better at explaining anything to you than someone with lots of achievements is able to."

As a coping strategy John was taking advantage of the university's flexible curriculum, choosing business and education modules, and only "the minimal amount of maths", although he found the fact that he enjoyed these other modules more than mathematics "upsetting". His curriculum choices though were rational and strategic: he chose non-maths modules which included smaller group sizes, since seminars offered environments in which he felt more able to ask questions ("you can relate to the teacher a bit better"), and where possible he selected mathematics modules with larger coursework components so as to reduce the demand on his short-term memory.

John connected his lack of enjoyment with no longer appreciating the purpose of learning mathematics; "…I like, being able to solve something that interests me, being able to prove something I get no joy from at all… I've sort of run past the point where I see the point of doing it." He seemed unwilling to compromise on this point:

"the way I've always seen it is maths solves problems... well now I just don't see that purpose any more. So I've sort of lost the enthusiasm for doing something I can't see the purpose in. and so my enthusiasm has shifted towards the business sides because suddenly there's a purpose."

The remarks offered above signpost shifts in John's exposure to the purposes of mathematics education. The move from A-level mathematics, which was "related to reality", to the more abstract content of university mathematics is indicative of the increased influence of goals involving the study of mathematics as an nonconcrete intellectual discipline; John recognised this himself in part, saying "I think being able to obtain a degree shows that you are capable of thinking in different ways… but personally for me I don't think it has helped." This shift in John's appreciation of the goals of mathematics appears to be conflated with John's own increased awareness of the role of his degree programme as a preparation for, and gatekeeper to, employment: "I've suddenly realised now I'm looking for a job."

Ultimately John had been severely disappointed by his choice of degree: "so in the last three years, what I've actually learned in maths, not the business or education stuff but in maths alone, is extremely insignificant… I've got a friend in the first year who asked me to – if I could help them. I couldn't – it was strange, 'cause I thought I would have been able to… it makes me wonder what I've really done… it just shouldn't be like that."

4.4.2 Adam's Story

Adam was also a final year undergraduate mathematics student and he reported similar experiences of mathematics at school. Mathematics had been "great… clear and logical… I never really had, I don't think, a lot of difficulty picking up anything while I was at school." Although he recollected some difficulties, these had been easily surmounted with time and practice, so that Adam didn't think he "would have too much difficulty" at university. Like John, Adam's identity as a mathematician was rooted in both achievement and outperforming others:

"I quite like the competitive side of things… I always wanted to be 100 per cent on the ball and know the answers to questions myself…. I remember being picked on by some of the teachers... trying to catch me out, but they, they weren't ever able to…"

Adam described his learning in this context as "almost effortless" and felt he had been able to ask questions in order to understand what was "going on" and why, so that in his mind things had seemed "to fit into place". Adam first experienced significant difficulty when studying towards the A-level in further mathematics. He had been originally motivated to study further mathematics because he needed the qualification, but after a breakthrough found it "satisfying" and "quite enjoyable again":

"I couldn't really see why I was doing certain things and I didn't make the links between what I was doing before and what I was doing after… (but after some time) *then it was just a natural extension of what I'd done, so it was really a, like a tipping point…"*

Adam had a tutor for further mathematics, who helped him see these connections, and of whom Adam was "free to ask all the questions I ever wanted." Here and elsewhere Adam's narrative is allusive to his preference for what Skemp (1976) might term a 'relational understanding' of mathematical concepts, and also to a desire to read a purpose into learning mathematics. However, Adam's perception of the purpose behind learning mathematics appeared to be subtly different to that of John. In particular, Adam more readily recognised purpose in nonfigurative mathematics:

"I like the structure of it… for example, you were working something out algebraically and then got a mathematical solution and then when it worked out quite neatly, there's something particularly satisfying about that. And the other side of it, obviously the competitive sort of, I'd like solving puzzles. I remember learning like trigonometric identities and things and you could see your start point, you could see your finish point, and just trying to fill in the gaps, that was always – it seemed more like a game than, than a chore rather or something that you know, I needed to do to get past an exam…"

This predilection for logical structure, in some ways suggestive of a nascent formalist philosophy of mathematics, might also indicate that Adam may have been more aligned to the practices and goals of university mathematics than John upon entering the course.

Adam decided to take a mathematics degree as it seemed to "fit better than other things". He had been working in a shop as a supervisor and had become interested in the managerial and financial aspects of his work. Although he recognised that a mathematics degree would offer him answers to some questions which school mathematics had left open, “it was more I think of a career motivation than anything else.”

Adam had expected university mathematics to be “harder”, but he felt he had not been fully prepared for the demands of the course:

“looking back now I wish somebody had told me, like, how different it would be…it’s not just it being harder… particularly in maths, there’s, there’s much more of a, of a need to persevere, to kind of get to a certain level of understanding with it. And I don’t think I ever really had that, enough of that…”

Similarly, he had not appreciated in advance how the practice of mathematics would shift:

“I didn’t really fully understand the nature of how you kind of study at, maths at university… a lot of the things that I came across were a sort of, you know, how do I kind of tackle this? I mean, there’s no set method for me to approach this, I kind of have to just you know, fight with it, look at what’s happening in other places and try and kind, kind of botch something together. So, the lack of routine and the lack of a structured approach was frustrating.”

Adam’s use of the terms “fight with” and “botch” here could be understood to communicate both a value judgement and an emotional reaction to his struggle; it contrasts suggestively with his earlier description of school mathematics as “almost effortless”.

The shift in the nature of legitimate mathematical activity undermined the strategy that Adam had used for realigning himself during his studies of A-level further mathematics:

"I think really, it's the lack of a structured response or seeing a problem, I never seem to know where to start… it felt like no matter how much practice I had, doing the exercises, doing you know, practice mock, mock exams and past papers and things like that, I never felt like I was a hundred per cent confident going into an exam thinking yes, you know, this question I'm presented with I'll know where to begin at least."

Changes in expectations and success criteria had also impacted on Adam's self-efficacy:

"At school, almost the goal in every question was to get to the answer. And that felt a lot more satisfying and productive in a way because I was always aiming for 100 per cent. And coming to university, that, that target comes down quite a long way…"

Adam had been further alienated by some aspects of university pedagogy: "*(At school)* I loved to be able to ask questions. And that's something that's lost at university when you're - when you're an invisible face in a crowd of three hundred. And on top of that, I'm doubting… whether I'm asking a question which I should already know, and maybe I've missed something silly. I've never had a lack of confidence in asking those kind of questions before." To this end, Adam found support elsewhere: "as much as like the lectures were of use and that's the introductory point, I never really felt that that probably helped me learn, I think more than anything it would have been working with friends." Here and elsewhere his dialogue suggests that, having felt marginalised in the main community of practice that is university mathematics, he became aligned with a subset of this community wherein struggle itself constituted legitimate practice:

"we all felt the same troubles so we, kind of, it was natural to kind of do that." When this had failed, Adam had used memorisation, but knowingly as a "last resort".

Adam had thought he "would always be a champion for maths" but now made a point of telling friends considering a mathematics degree that "you have to be aware of how different it is, not just how hard it is, but how different it is." He still spoke favourably of what he defined "school maths" though: "I'm still you know a champion for that side of things, I still tell them it is great, but university maths maybe not so much." At the time of the interview he was considering moving into something practical involving finance, noting "it's the practical side of things which I think I like to see has application in the real world. And that's I think a big thing that was missing over the last three years."

Whilst Adam had successfully negotiated the practicalities of attaining a mathematics degree, his experiences had left him frustrated and perhaps even ashamed:

"But really, you feel quite hopeless at the end… every year, it's not necessarily during exam times but, there's always a period in the term where you just feel like this is hopeless, I, can tell it doesn't matter what I do, this is never going to work… I know there's a lot of options and resources there for you to support… I remember trying and trying and then you just sort of reach this point, you're like oh it's not worth it any more. And I sort of wish that hadn't happened. Sorry."

4.4.3 Mark's Story

Mark was also in the third and final year of his mathematics degree. Like the preceding students, he had constructed his mathematical identity in light of achievement and competition; he had found GCSE mathematics to be "quite easy", and this continued into A-level:

"*…you do find that you had to work a bit more, but I think because I was good at it, I could sort of not work but still get the same marks as people around me who did work a lot more."*

Mark believed that his mathematical trajectory had been influenced by those around him; both sides of his family had been "maths-orientated" and so he assumed he "had a predisposition towards maths." He also felt that he had "certainly always been pushed towards maths" by many of his teachers. He recalled that one teacher had been "sort of proactive and would show us different sorts of things and ideas…. the millennium problems, and things like that."

Mark reported being marginalised by some of the pedagogical practices of university mathematics. At school he had been secure with the practice of "this is the idea, go try it twenty times", but he felt less included in the learning process now: "I'd say the main thing I found at university is a lot of the time you're talked at." This did "depend lecturer to lecturer" though; for instance Mark praised one lecturer because "he'd state a theorem, explain the theorem, how to use it, and then explain why it worked, and then write the proof. So we'd have an understanding of what the theorem did, why it worked, and then the proof, sort of made, you know, completely made sense." However, Mark also suggested that this course was easier because there was less to remember: "admittedly, that course didn't have too many definitions in, so…"

Much of Mark's narrative is similarly framed with attention to his memory, and he rationalises his difficulties with university mathematics as being in part consequent of a decline in memory:

"My memory's, for some reason has got unbelievably poor… I mean, like for exams, I can't memorise a proof, so I either have to work it out there and then or just hope I can remember sort of snippets of it…. I've always struggled, certainly, yeah, pretty much since I've got to uni… to remember certain things like definitions and proofs…"

Throughout his account there is a tension in Mark's narrative between appreciating university mathematics and becoming frustrated with it. On the one hand he recognised value in university mathematics, seeing "where everything comes from and how it works and how it's defined… what you can do with the things you were taught at school and how you can extend them further." Yet in order to explicate his perceived difficulties he repeatedly resorts to claims about the load on students' memories:

"during an exam you've got so many definitions you're expected to remember, stuff from previous years as well, and just to be able to like, just regurgitate all these random theorems and definitions they expect you to know is, just gets a bit… extreme."

All of the undergraduates in these interviews were on course to successfully graduate; here Mark felt that he was able to aim for an upper division second class honours degree at the end of the year. Therefore one possible reading of this narrative is that Mark was in some measure aware of his success at undergraduate mathematics, but that his mathematical identity and self-efficacy was being undermined by a persistent learned expectation of high marks and out-performing others. The inherent contradictions are thus explained by appealing to an over-reliance on memory.

Further markers of Mark's mathematical identity were offered when Mark talked about preferring to work with other people than on his own. He described working with a group of friends with complementary thinking styles, and alleged that he was "more of an intuitive thinker than like methodical… I'll try and spot a pattern, same as most people do, but I can generally make leaps that most people don't see, a lot of the time." This quote may be taken to signal a partially understood indicator of what qualifies as success, inferred from Mark's new community of practice. Certainly his claim is simultaneously bold and tempered; Mark continues to support his mathematical identity by comparing himself against others, but includes a final qualifier as an escape clause, explaining away less successful instances. Mark's tendency to evaluate himself against others was apparent once more at the end of the interview, when Mark compared his university course to that of another university, arguing that his own course was more difficult.

After graduating Mark was considering taking a second degree in medicine. He claimed to be happy that he was leaving mathematics behind: "I wouldn't enjoy using it in the workplace, 'cause I can't see where I could use it where I'd be happy with the job I had." He saw his options as limited, offering that "if you don't want to earn money for the sake of earning money, and you can't, well I certainly can't teach it, then there's not really much else you can do with it."

4.4.4 Cathy's Story

Cathy was a mathematics undergraduate in the second year of her degree. Whilst she too related that mathematics at school had been "really easy", her account centred not on her individual attainment, but instead on the community of learners that had existed at school. At secondary school she had worked with an "amazing maths teacher for five years… and we had a really good maths class, like everyone was really good friends… I always loved maths then." At A-level she met a new mathematics teacher "that was also amazing":

"…he had like really good crack with us, like he was really funny and he knew, he used like banter… And he was really, really fair… And he had really good ways of learning stuff, like loads of songs, and had… really good ways of making us remember stuff. And he was really enthusiastic as well… I still sort of see him sometimes now, like if I go back to school just to see my teachers."

Cathy had considered a number of subjects before choosing her degree; she mentioned both economics, which she had rejected after finding out more about the course, and education, which she had first considered because she had "always loved children." However, she elected not to take a joint honours degree in education and mathematics, because she feared that the limited mathematics content would restrict her employment options. Her mum offered consonant advice: "if you're doing education in your degree, you're kind of stuck with education, whereas if you do a maths degree you can still be a teacher, but you can do other things as well." Hence with a lot of deliberation, and after some final encouragement from her mathematics teacher who said she had a “really, really big talent for it”, Cathy applied since “getting a maths degree will probably take you quite a lot of places… you can pretty much do anything you want if you’ve got a maths degree.” In this way Cathy offered a lot of detail about her decision making process, demonstrating explicit consideration of the role of higher education as a conduit to employment opportunities.

Cathy clearly regretted her decision to take a mathematics degree. Perhaps because she was in the middle of her degree, she offered a number of explicit comments designed to try and justify her persistence and rationalise her situation. These included further reflections on the relative worth of a mathematics degree in the employment market:

“*…believe me the last few years like every single week I’m like why did I do a maths degree?... you do convince yourself that it’s worth* doing because like, *it is really highly respected… no matter where you go, and try and get employed, everyone will be impressed that you’ve done a maths degree, so it’s worth trying to stick it out… if you’ve only got one really outstanding talent, and you’re like I’ve got to do that, I’ve got to do it. But I probably could have done any degree I wanted, and I just didn’t – it makes it harder, in a way… I just, despise maths at university. Like, really, really don’t like it. And I think if I didn’t have any* extra-*curricular activities to keep me here then I really wouldn’t be here anymore.”*

Although Cathy mentioned changes in university mathematics such as the introduction of new symbols and the emphasis on proof, much of her unhappiness seemed to stem from the learning environment and changes in pedagogy associated with university mathematics.

"I think I always had a really good relationship with my teachers, like you could have gone to their office in a lunchtime and asked them if you were stuck or anything like that, in lectures like I wouldn't even dare put my hand up. I wouldn't, I just wouldn't dare put my hand up and ask a question… anyone who did got laughed at, if, if they asked like a stupid question."

Although she allowed that "the sort of really cocky boys" might offer a question if they had found a mistake in the lecturer's working, "no one ever like puts their hand up and goes 'sorry, can you go through that again, like I don't really get it?'" Her attempts to approach university staff had left her further marginalised:

"I sometimes went to see my tutor, but he was only, was only really good at his area, like his specialism in maths… they're so clever that they don't understand how people can't understand it… Like, they'll say things like so obviously this follows, and this is obvious, this is trivial, and you're like ok, this just makes us feel stupid because anything that they say is trivial that I don't understand, I then feel completely stupid."

This last quote has a particular resonance with John's comment about explanations from people who are highly qualified in their field. Once again though, not all lecturers were labelled as poor; for instance she said of one that "he went slowly and he wrote in full sentences, which sounds like a really small requirement, but it just, it helps so much."

Cathy's discussion of the lectures themselves was also critical; although some lecturers provided lecture notes which she could personalise, annotate or even complete during lectures to support her learning, many lecturers expected their students to copy down everything for themselves at speed: "…*(some lecturers)* go really, really fast… even one tiny lapse of concentration means you've lost it." Conversely, Cathy offered that "every time I'm in a seminar I learn a hell of a lot more than in a lecture. Loads more. Because, I think, you're given the opportunity to put your hand up, you don't feel as stupid…" Unfortunately, most of the seminars Cathy had experienced had been offered for options outside of the mathematics department.

Cathy was heavily involved in extra-curricular activities at the university and this seemed to serve not only as a release for her frustration, but also figured in her rationalisation of her current pathway:

"I've been for like a few like little interview things like lately, and all they're interested in is what you've done extra. They're not interested at all in your degree. Like, as long as you can put down, I achieved a 2:1 or above… As long as you can put, tick that box, then after that they don't care anything about your degree. All they care about is your hobbies and what roles of responsibility you've taken on and what societies you're in, and what else you do. So, to me, like, I shouldn't be concentrating on my algebra, do you know what I mean?"

To this end Cathy's strategy was different from those of the other undergraduates in as much as it focused on doing the minimum amount of work rather than devising strategies for coping with the demands of the course. It is thus possible to infer from Cathy's narrative a greater influence of a neo-liberal discourse, framing university education as primarily a process of self-accreditation, and also to argue that Cathy is using this understanding to rationalise and defend her withdrawal from mathematics.

Nonetheless, when prompted Cathy did recall some strategies such as working with friends, researching online or using social networking when she was stuck with assignments. This last approach seemed also to involve a process of self-assurance:

"…if you're getting stuck on an assignment just put it on your Facebook status and like ten minutes later you'll have like six comments: I'm really stuck as well! It's like phew, it's fine as long as everyone's struggling, I'm fine."

In this vein Cathy admitted that she was "really competitive… I used to like being the best, but now that I can't be the best, I just need to know that everyone else is as bad as me." She acknowledged that some people might be able to learn mathematics without struggling but argued that "they're probably like autistic or something… it's very, very rare that you'll have like a good personality, good social life and not struggle at all..." These comments are recognised here as both emotive and defensive. Like Mark, she also used comparisons to support her mathematical identity when she compared her university favourably against others.

There was substantial evidence that Cathy's experiences had impacted her identity; despite having attained four 'A' grades at A-level, Cathy said that her assignments were "just so hard… probably just 'cause I'm not very bright…. I think I've reached the capacity of my mathematical ability." This was not the only possible discursive inconsistency in her narrative: despite helping to run the university dance society, Cathy explained some of her difficulties in solving mathematics problems by saying "I think I'm not very creative."

Ultimately, Cathy had ended up constructing a joint honours degree in mathematics and business studies, and at the time of interview was “so excited” that her final year would contain no mathematics. She said that she would consider returning to mathematics in the future in the capacity of teaching, because she remembered how much fun and how “do-able” it was at school.

4.5 Discussion of the Local Research Questions

This section will consider how the narratives of these four learners illuminate the three local research questions, then briefly go on to consider how this evidence further speaks to the two global research questions. A further synoptic discussion is offered in chapter six.

4.5.1 Local Research Questions One and Two

The first and second local research questions were worded as follows:

- **How do the experiences and mathematical trajectories of these learners, particularly their decisions to leave mathematics behind after graduating, reflect the competing goals and roles of mathematics education?**
- **What changes and developments have these learners recognised in the different stages of their mathematical learning? In what ways do these reflect changes in completion and co-operation between the goals and roles of mathematics education?**

The narratives presented above conflate the concerns of these two questions; the learners are knowingly conscious of changes and developments across the stages of their mathematical learning, using this awareness to rationalise their experiences and defend their decisions. To this end these two local research questions will be discussed concurrently.

It is clear in each of the narratives that for these learners their figured worlds of mathematics have changed and, in tandem, so have their understandings of what constitutes mathematical learning. Both of these shifts have impacted upon their mathematical identities, and in light of this they have made the decision to leave mathematics behind; in the words of Mark: "I can't see where I could use it where I'd be happy." Beneath these shifts there are undoubtedly changes in the way that the various goals and roles of mathematics education are understood by each of the learners, but these changes are not as clearly signposted as they were in the data in chapter three.

One reading could be that an increased attendance of 'old humanist' viewpoints, together with the much greater worth afforded to abstract intellectual pursuits at university, might dissuade undergraduates from continuing to identify with mathematics as a field of study. It is certainly the case that the pre-eminence of proof, mathematical analysis and the dependence on symbolic notation were all cited by these undergraduates; for instance, John offered that "*the maths that we do at university is much more corollary, theory, proof... which is shame, because the stuff which I enjoyed, we no longer do. And we're suddenly doing something which isn't – it isn't maths that I knew, that I enjoyed and that I was good at.*" Such factors certainly reflect a move from seeing mathematics as a field with immediate application to a subject more concerned with rigorous, reasoned thinking and were undoubtedly a contributing factor.

In many respects though, this is too simplistic a reading of relevant curricula, since undergraduates will have been partially aligned to many aspects of nonconcrete practice before. Both A-level mathematics and further mathematics explicitly differentiate between ‘pure’ and ‘applied’ mathematical content, require significant recognition and use of symbolic notation, and include instances of proof. This earlier shift was evident in Mark’s comments: “at GCSE it was all about computation… *(then at)* A-level the focus sort of shifted more to the like analysis of what was going on… I didn’t really think much of it at the time.” Adam even commented that he enjoyed tasks to do with structure and often viewed them as puzzles. Hence whilst changes in curriculum content do indicate changes in the relative prevalence of the goals of mathematics education, changes in content alone do not adequately explain the narratives offered above.

A subtler argument is therefore that some of the goals of mathematics education have, whether through tradition, context or necessity, become allied with particular pedagogical techniques; thus purpose is mediated through pedagogy. For instance, the ‘ten questions’ model of mathematical activity mentioned by John as a feature of school mathematics is readily defensible when the principal aim is to develop skills of quick and accurate calculation which might be used in an everyday or workplace context; for here, as Adam stated, “the goal in every question was to get to the answer.” Conversely, when the goal is to develop mathematical thinking and probe mathematical structure, each question is more likely to be distinct, leaving students such as Adam not knowing “where to start”. For learners who have constructed and confirmed their mathematical identities using absolute success criteria, such as the ‘one hundred per cent’ mentioned by John, Adam and Cathy, this change in the form of questioning can have acute and damaging effects. Having valorised results over resilience for so long, they are unable to successfully modify the ways in which assessment informs their mathematical identities. This was certainly the case for Cathy, even though she was in some measure aware of the resulting absurdity: "(if you get for an assignment) *60 per cent, that's actually technically quite good, cause it's like a 2:1 at university, which is good enough to get you into most of the major companies and stuff, but I see 60 per cent and I'm like oh my God, I'm failing, I'm so stupid."*

Others of the changes in pedagogy that were noted by the undergraduates are arguably more consequent from pragmatism than philosophy; in particular, the increase in class size and the introduction of lectures. Regrettably, these might exacerbate the concerns voiced above; the drastic decrease in individualised support, together with the loss of an accessible personification of the field in the figure of the classroom teacher, could be seen to contribute further to trends of marginalisation. This is explored further below in section 4.5.2.

The roles of mathematics education also feature in the trajectories described by the data. The role of mathematics as cultural capital can again be detected in each of the narratives, not only through direct references such as Adam's "career motivation" and Cathy's "2:1 or above" remarks but also in the participants' common decision to complete the degree course and qualify despite their difficulties. Cathy's comment that "you can pretty much do anything you want if you've got a maths degree" similarly reflects the role of mathematics as a gatekeeper qualification, but is tangential to a possible move from alignment to misalignment within the purposes of mathematics education. The design, content and delivery of mathematics at school is such that a strong argument can be made for GCSE mathematics being a 'general' qualification in both an epistemic and social sense: it supports the learning of skills and techniques useful in many fields, and facilitates entry to a wide range of opportunities in further education and employment. However, the changes in content and perspective detailed above demonstrate that whilst a mathematics degree might be 'general' in that it is valued by a wide range of employers, its nature and content are both much more specific than was the case at school. It might be that a preliminary underestimation of this variance could also help to explicate some of the narratives of undergraduates who choose to leave mathematics behind after graduating.

4.5.2 Local Research Question Three

- **How have these learners responded to, and made sense of, these observed changes and developments?**

In the main, the learners appear to have responded to the changes and developments discussed above by continuing with their degree courses but constructing marginal identities for themselves; for instance Adam saw himself as "an invisible face in a crowd of three hundred" and Cathy sat in lectures but "wouldn't dare put my hand up and ask a question". This is highly consonant with other research into undergraduates' mathematical identities (for instance Solomon 2007a) and thus speaks to the validity of these results. The nature of this repositioning varied between the learners. Whilst John and Cathy explicitly moved away from mathematics, taking optional modules offered by other faculties, Adam utilised his experience of struggle instead to align himself with a counter-community of learners.

The undergraduates interviewed also described a concomitant affective response, and the narratives were often emotionally charged, for instance when Adam described feeling "hopeless" or when Cathy talked about feeling "despair". In cases such as these an appeal to futility could be read as an emotional refuge, albeit one which comes at a significant cost to the undergraduate's agentic identity and self-efficacy; for instance Mark's construal of himself as having an "unbelievably poor" memory.

There was also some evidence of a similar demarcation process to that noted in chapter three; for instance when Adam describes himself as still being a "champion" for school mathematics he is deploying a distinction between 'school mathematics' and 'university mathematics' which allows him to maintain in part his earlier agentic identity by foregrounding changes in the nature of mathematics, rather than changes in his activity as a mathematician.

In their research concerning American undergraduates switching majors, Seymour and Hewitt (1997) discovered that "what distinguished the survivors from those who left was the development of particular attitudes or coping strategies" (p.30). These narratives form accounts of some of these attitudes and strategies, but they also suggest that some of these come with an associated price, both to the individual and to a society which is attempting to address a shortfall in STEM industries.

4.6 Discussion of the Global Research Questions

The two global research questions were first presented in section 1.3 as follows:

- How do the experiences and mathematical trajectories of learners reflect the competing goals and roles of mathematics education?
- How do learners navigate and make sense of competing or co-existing goals and roles of mathematics education? In particular, how do they make sense of their own mathematical purpose?

The close wording of the local research questions means that these global questions have largely been addressed in the preceding discussions. Further, a full discussion of all of the data follows in chapter six, and so extensive comments are not included here to limit repetition.

Notwithstanding, it should be noted at this stage that the typical shape of the undergraduates' trajectories offer an interesting contrast to those of the prodigals, and a certain symmetry can be read into the ways in which the role of mathematics as cultural capital can guide decisions.

In the cases of the prodigals studied in chapter three, their mathematical trajectories began with recognition of the social role of mathematics as cultural capital. This recognition served to motivate the prodigals to apply for an adult education course which in turn precipitated shifts in each learner's recognition of the goals of mathematics education. In this way salient epistemic goals became more attendant with the social and political roles of mathematics, encouraging each learner to maintain an interest in mathematics or even pursue further study.

On the other hand, in the cases of the undergraduates researched in this chapter, their mathematical trajectories began with prevailing goals and roles coupled together; when deciding to undertake a mathematics degree they felt that mathematics was useful and worthwhile, and also recognised the social worth of a mathematics degree as a qualification. However, an alternative balance of the goals was foregrounded at university so that the students aligned themselves less with the practices of mathematics education and focused more on the roles, eventually departing with a valuable piece of cultural capital but a damaged perspective of themselves as mathematicians.

In many ways the preceding paragraphs are overly simplistic caricatures; in particular the previous chapter has already noted that some experiences can have long-lasting effects that may nullify or amplify responses to new learning contexts. Nevertheless, these vignettes do articulate two contrasting ways in which the interactions between goals and roles can play out. As a result this thesis has illustrated that as learners move between different learning communities and cultures, shifts in the ways that these aims co-operate and conflict can affect learners, and that these effects can be positive or negative.

4.7 Summary of Sustained and Developing Categories

All of the categories defined in light of the chapter three data were sustained, although some were developed to support the observation of resonances between contexts. These categories are listed below, with changes highlighted in italics:

- the import of mathematics as a gatekeeper subject and as cultural capital

- ability grouping and competition *and its contribution to identity-building processes*
- emotional responses to success, difficulty and failure in mathematics
- teachers *and lecturers* as model practitioners of mathematics and the import of the teacher-learner relationship

This last category was paired with a new category after it was felt a dual perspective would better describe the emergent data:

- pedagogy and perceptions of legitimate participation in communities of practice

The category ‘explanations, contexts and connecting mathematical learning to the ‘real-world’ was reworded and expanded, better to include all the data sets:

- concrete and non-concrete mathematics

Finally, two new categories concerning coping strategies and rationalisation were introduced after common codes were spotted in the undergraduate and adult learner data:

- the place of memory in learning mathematics
- partitioning mathematics, potentially for psychological advantage

These categories then contributed to the development and the conduct of the research detailed in the next chapter, as represented in figure 2.1.

CHAPTER FIVE: EXPLORING THE EXPERIENCES AND PERSPECTIVES OF GCSE CANDIDATES NEAR TO AND BENEATH THE 'BORDERLINE'

5.0 Introduction

The findings of the preceding chapters have highlighted the import of school experiences, demonstrating their primacy in both forming a learner's mathematical identity and facilitating an individual's procurement of cultural capital. Accordingly this final data chapter takes as its subject two concomitant groups of learners working towards a strategic GCSE mathematics qualification whilst at secondary school: one group whose members are considered to be on the borderline of achieving the watershed C grade, and a second group consisting of students considered to be below this borderline and unlikely to attain this level of qualification before leaving school.

Both of these groups exist explicitly at the intersection of multiple goals and roles of mathematics education. As outlined in chapter one, each of the considered goals of mathematics education can potentially be inferred to some degree from different elements of school practice. The gatekeeper role and high-stakes nature of the GCSE mathematics qualification is then made clear to students through grade-centred resources, assessment practices and highly visible in-school strategies such as 'intervention' or 'booster' classes intended to increase the proportion of learners attaining a C grade (de Waal 2008). Some teachers have also been observed attempting to motivate students with 'fear appeals', messages which highlight the occupational and educational consequences of failure in the

GCSE examination (Putwain and Symes 2011). The interplay of the purposes of mathematics education here is further complicated by the fact that the same grades which are used to evaluate the students' attainment are also used to assess schools (Goldstein and Leckie 2008).

This chapter will explore how these two groups of students experience learning mathematics, and in particular question how these learners' inferences about the meaning of their learning might shape their conceptions of both mathematics and their own mathematical purpose.

5.0.1 Localising the Research Questions

Learners working at the borderline of a C grade in GCSE mathematics and learners working below the borderline are distinct in a number of practical and theoretical respects. Nevertheless within the remit of this thesis the parallel elements within the circumstances of these groups are sufficient to allow for both to be studied using the same research questions and methodology, so as to support comparisons.

Section 1.3 presented the global research questions of this thesis:

- How do the experiences and mathematical trajectories of learners reflect the competing goals and roles of mathematics education?
- How do learners navigate and make sense of competing or co-existing goals and roles of mathematics education? In particular, how do they make sense of their own mathematical purpose?

The first of these questions has already been addressed in a broad sense in chapter one, through considering how a learner might steer their trajectory in light of the import afforded to the C grade in GCSE mathematics, and how the use of GCSE-related statistics in league tables might result in schools differently awarding attention to certain groups of students. However, there is arguably less potential within the cohorts of the current chapter for learners' trajectories to be examined individually through exploratory research. The trajectories of these students are less unique or unusual than those of prodigal learners, or of undergraduates leaving mathematics behind after graduating. At this stage of their educational histories, these students' mathematical experiences would have been almost exclusively limited to compulsory schooling, within which there is limited agency at the level of the individual; every learner in England is statutorily required to study mathematics and, with only a few exceptions, all attempt the GCSE examination.

To this end the global research questions were localised for these cohorts by concentrating on the learners' views on the nature, practice and purpose of mathematics education. This approach offered comprehensive coverage of the second global question, after which attention could be directed towards the first global question, through appraising the collected evidence about mathematical experiences which the learners themselves considered to be salient, or over which they considered themselves to have agency. Three inter-linked local research questions were constructed as follows:

- **How do the learners view the subject area of mathematics?**
- **How do the learners view their own study of mathematics?**

- **How do the learners position themselves with respect to the practice of mathematics?**

A light parallel can be drawn between these three questions and the structure of the second global research question: the first local question could be interpreted as being more concerned with the goals of mathematics education; the second local question could be seen to be more likely to generate responses about the roles of mathematics education; and the third is concerned with each learner's sense of mathematical purpose. Notwithstanding, the interdependence of these three questions is extensive; in this way the design of these questions was intended to explicate the global research more fully, and also support a comprehensive convergent validity. Further, these local questions have the potential to speak to the first global research question, as the learners' experiences will have been central factors in the establishment and evolution of their views.

These local research questions were operationalised into a localised methodology which is described in section 5.2. The findings of this research are presented in sections 5.3 and 5.4; the contribution of these results to the global research questions follows in section 5.5.

5.1 Literature Review and Theoretical Framework

This section summarises the parts of the overall literature review which relate to this particular component of the thesis research and were considered central to these groups of learners, namely research concerned with ability grouping, tiered assessment, and their effects on secondary school mathematics learning. The summary of research into ability grouping and mathematical identities in section 5.1.2 should also be understood to inform the theoretical framework of this thesis.

This portion of the literature review began with a selection of journal articles, books and reports known to the author through previous research and teaching. However, the specific nature of this field, together with the existence of a semi-standardised vocabulary, facilitated a later full systematic search which was carried out in 2012 using the Educational Resources Information Center (www.eric.ed.gov). The search parameters were adjusted to find all articles written since 2000 and regarding secondary education which referenced 'mathematics' and at least one of 'setting', 'grouping' or 'tiering'. Articles that referenced either a possible or observed impact on attainment or affect were then included in the final literature review which is summarised below.

5.1.1 Ability Grouping, Attainment and Affect in Secondary Mathematics

Ability grouping, or setting, is standard practice in contemporary English mathematics classrooms. Although mixed-ability teaching has been more widespread in the recent past, setting has become dominant; in their literature review of pupil grouping, Kutnick et al. (2005) report that 83% of Key Stage Three and 100% of Key Stage Four mathematics classes are taught in sets (p.8). Setting can be justified in terms of intended teaching and learning outcomes, particularly through claims that it supports appropriate pace and challenge for all learners, and there is evidence that school students are themselves heedful of these potential benefits (Hallam and Ireson 2006). Nevertheless, it is certainly also an organisational strategy intended to reflect tiered assessment structures, and one which has been increasingly subject to criticism in recent research and reports.

There is a growing body of evidence that overall attainment outcomes of cohorts experience little change when learners are grouped by ability, as although setting can advantage students in higher sets, it disadvantages those in lower sets (Kutnick et al. 2005, p.49). For mathematics in particular, students with similar prior attainment do better in higher sets, but make less progress in lower sets (Wiliam and Bartholomew 2004; Ireson, Hallam and Hurley 2005). These results not only belie many of the assumptions behind setting but also suggest a more complex picture of advantage and disadvantage where progress in learning mathematics may be unduly influenced by school organisation. They also invoke concerns regarding social inequity; Muijs and Dunne (2010) found that students' social backgrounds and levels of special educational need were both significant predictors of setting. One implication of this finding is that setting, possibly in tandem with tiered entry for the GCSE mathematics examination, could be considered to constitute a form of symbolic violence (Bourdieu and Passeron 1990), wherein the socially legitimised judgements involved in school organisation disproportionately disadvantage certain social groups.

Beyond attainment, much of the criticism in the extant research concerning ability grouping in mathematics (for instance Boaler 1997) comments on how this practice can negatively affect students' engagement; in their review of the general literature Kutnick et al. (2005) hold that "the relationship between ability grouping of pupils and disaffection, in particular of pupils in the lowest groups, has been well demonstrated" (p.49). This concern is known to be salient for the cohort researched here: Kyriacou and Goulding (2006, p.12) identified grouping as one of four key areas in their systematic review into research concerning pupil motivation in Key Stage Four, citing the others as pupil identity, teaching for engagement and innovative methods (p.12).

Setting may further have long-term impacts on students' academic self-concepts. Boaler, Wiliam and Brown (2000) conducted a four year longitudinal study into learners' attitudes towards mathematics as they moved from mixed-ability groups to sets. They found that almost all of the learners they interviewed were unhappy with the change, and noted that differences between the sets in both pedagogy and teacher expectations had begun to polarise the learners' attitudes. They subsequently argued that "students are *constructed* as successes or failures by the set in which they are placed as well as the extent to which they conform to the expectations the teachers have of their set" (p.643, their emphasis). In this way, the affective bearing of ability grouping can also be understood to inform learners' mathematical identities.

5.1.2 Ability Grouping and Mathematical Identities

The action of placing a learner in a group defined by ability embroils both theoretical assumptions and psychosocial consequences. The practice of setting is consonant with fixed, as opposed to incremental models of intelligence (Dweck 2000). This, together with the fact that a majority of students (estimated by Dixon (2002) at 88%) do not move between sets in their school mathematical careers, can be argued to contribute to what Boaler (2009) terms a "psychological prison" (p.112). Students thus may be at risk of conceptualising themselves as having a particular, static aptitude for mathematics which will determine their future trajectory, regardless of their good intentions or best efforts.

This scenario has been broadly supported by recent research. For example Ireson and Hallam (2009), studying students in 23 secondary schools across Key Stage Four found that students' general academic self-concept was related to the extent which ability grouping was used in their school; subject-specific elements of their self-concept then related significantly to each learner's position in the grouping hierarchy. Nardi and Steward (2003), in their study of disaffection in the mathematics classroom, hold that stratification imposed by setting encourages "anxiety and nervousness" (p.358) in many learners, and can also impact negatively on high achievers by inculcating a sense of elitism.

Despite this strength of association setting appears not to influence identity uniquely or independently; for instance Hallam and Deathe (2002) found that set placement did not have a consistent effect, but that it "seemed to be mediated by the quality of teaching" (p.7). Further, aspects of self-concept were reported to improve up to Year 9 and then decline in Year 10, almost certainly in response to the pressures of beginning formal preparation for the GCSE examination. Solomon (2007b) analysed some accounts given by Key Stage Four learners and found that setting had a major impact on some learners' self-identities, but was less influential on the identities of others. In line with the discussion of section 2.3.2 of this thesis she holds that it is not only the learners' experiences that contribute to their identity-building, but also their own discursive accounts of those experiences; further, she notes that "gender is crucial in the development of participative identities" (p.17).

This thesis continues to assume the position that identity is neither fully essential nor wholly intrapsychic. In light of the current discussion and the findings of the previous chapters, this present research holds the theoretical position that ability grouping is a significant influence on the identity building processes of secondary school learners. Since learners predicted C/D grades and those predicted lower grades will have been differently set, this present research both predicts and expects differences in the ways that these two groups consider and express their mathematical purposes.

5.1.3 Tiered Assessment in Mathematics

Formal assessment in mathematics has long been noted as problematic (for instance Cresswell 1994) as aggregation and awarding methods have to balance demands of reliability, comparability and transparency. Against this background, tiered assessment can afford a degree of specificity; after the spirit of Cockroft (1982), a tiered GCSE paper is structured to allow students to demonstrate more of what they do know, rather than reminding them of what they do not.

From 1998 GCSE mathematics was assessed using a three tier system. The ranges of grades on the three papers were D to G, B to E and A* to C, with candidates who failed to attain the lowest grade on any of the papers being awarded a U grade. However, this was noted to be problematic (for instance Burghes, Roddick and Tapson 2001); not only were there two instances of overlap which needed to be monitored, but candidates sitting the foundation paper were denied any chance of achieving the key C grade. Criticisms such as these led to the introduction of the present two tier system, first taught in 2006.

Under the two tier system, GCSE mathematics candidates are either entered for a foundation paper involving grades C to G, or a higher paper on which candidates can achieve any grade from an A* to an E; U grades are again awarded to candidates failing to attain the lowest included grade. This change has led to further criticism though; for instance MEI (2009b) holds that the increased breadth of study means that the higher paper no longer serves as sufficient preparation for A-level, and that candidates with a weaker algebraic facility are now more likely to attain a B or a C grade. It is also of concern that Wheadon and Béguin (2010) conducted statistical analysis of one two-tier mathematics assessment and claimed that candidates in the foundation tier were typically over-rewarded, whilst those in the higher tier tended to be under-rewarded: “approximately half of the 17% of higher tier candidates who received a grade D have an imputed standard of grade C on the foundation tier paper” (p.295). In summary, tiering continues to be a contentious issue in mathematics education, and its effects on pupil experience are not fully understood; in the words of Kyriacou and Goulding (2006), “more research is needed on the impact on students of being in a low set for mathematics where the whole class knows that they will be denied access to the highest grades at GCSE” (p.15).

5.2 Methodology

The localised research questions for this component of the research were constructed as follows:

- **How do the learners view the subject area of mathematics?**
- **How do the learners view their own study of mathematics?**
- **How do the learners position themselves with respect to the practice of mathematics?**

A two stage mixed-methods approach was developed to address these questions. The first stage of the research consisted of a questionnaire which primarily gave rise to quantitative data. A large-scale approach was chosen to take advantage of the substantial sampling frame; further, a large amount of data was required to support multiple comparisons between the various factors recognised in the discussion above as potential influences on learners' views. Although a quantitative mode might be considered uncharacteristic when researching internal and personal issues of this nature, such a method was considered expedient to structure and enable the requisite comparisons between groups, as well as to reduce the risk of researcher bias in their commission; there is also a rich body of pre-existing tools which can be utilised to explore affective concerns in the learning of mathematics (Chamberlain 2010).

The second stage of the research deployed a semi-structured interview tool which was intended to facilitate a greater depth of response and support convergent validity; participants were selected in a manner that was representative of the range and distribution of the quantitative responses. This stage allowed for the collection of narratives which it was hoped would ultimately facilitate fuller coverage of the first global research question, and thus enable keener comparisons between the data from all three components of this thesis in line with the expectations of grounded theory (Glaser and Strauss 1967).

5.2.1 Sampling and Access Issues

Although this research considers all students in Key Stage Four, it was determined at an early stage only to include students who were in the first year of this phase, Year 10. This decision reflected a number of concerns; chiefly that the views of students in Year 11 might be overwhelmingly dominated by apprehensions about imminent examinations, and that a focus on Year 10 was both more ethical and more likely to be approved by participating centres.

Seven secondary schools known to be amenable to educational research were originally approached, all of whom expressed interest in taking part in this study. Access was first negotiated through known contacts in each school, and then details were passed on so that the head of department in each school became the chief point of contact. Access was willingly granted by all centres on the condition that an anonymised summary of the results was shared with each centre after the completion of the research. One school failed to maintain contact during the planning stage and another was unable to take part in both stages of the research so these centres were withdrawn. The five remaining schools were considered sufficiently diverse in terms of both demographics and performance to support comparisons in the analysis stage; details of each school's characteristics are given below.

All five schools grouped by ability in mathematics. The head of the mathematics department in each of the five schools identified sets which they considered to contain either learners targeting a C grade or learners understood to be aiming for the lowest grades at GCSE; for concision these groups will be denoted from this point using the terms 'borderline' and 'lower grade' learners respectively. The nomination of teaching groups by centre staff was deliberate, so that the sample would inherently involve the same discourses of identification that the students would have been exposed to.

A brief portrait of each of the centres is presented here; each centre had the chance to comment on an early draft of this description at the time in order to support reliability and ethical practice. After contemporary government practice, the measure of achievement used in the pen portraits is the percentage of students achieving five A* to C grades at GCSE including mathematics and English; the 'CVA score' refers to the reported contextual value added figure that had been calculated based on pupil progress from Key Stage Two to Key Stage Four. The included statistics are given as rounded figures or in terms of national averages to protect the anonymity of the centres. In addition to the complication detailed below for School C there were some minor omissions arising from pupil absence, but few issues of non-response on the questionnaire itself; six incomplete questionnaires and a further one whose teaching group was ambiguous were removed prior to the analysis stage and do not contribute to the figures here given.

School A was a mixed 11-16 state school with approximately 650 students. It served a very deprived catchment area within a large industrial town. The most recent Ofsted inspection had rated the school as satisfactory and improving. Achievement rates were below the national average, and the CVA score was close to the national median.

In school A, students in Year 10 were split into two bands, and mathematics was taught in sets within these bands. The school followed a linear GCSE programme, (assessed wholly through a terminal examination), although some students were entered in the November of Year 11 if they were deemed ready so as to give them two chances at the examination. The school volunteered five teaching groups: three borderline sets and two lower grade sets (n=81).

School B was a mixed 11-18 state school with approximately 1250 students. It served a relatively affluent catchment area in a rural area. The most recent Ofsted inspection had rated the school as outstanding. Achievement rates were above the national average, and the CVA score was close to the national median.

Students in Year 10 were set as a single cohort, which was considered by the head of department to be a little more able than usual. The school followed a linear GCSE programme where the highest achieving students were entered for their GCSE at the end of Year 10, and the others followed in the November of Year 11. All students were then allowed to retake their GCSE mathematics at the end of Year 11, in order to improve their grade or to sit the examination within a higher tier of entry. The school volunteered three teaching groups: one borderline set and two lower grade sets (n=49).

School C was a mixed 11-18 state school with approximately 800 students. Its catchment area was a socially deprived area within a large city. The most recent Ofsted inspection had rated the school as satisfactory. Achievement rates were below the national average, and the CVA score was close to the national median.

Students at school C were set as a single cohort. Each pupil sat a linear examination in GCSE mathematics at the end of Year 9; this measure was introduced partly to replace the recently abolished SAT in mathematics and partly to familiarise students with the GCSE examination process so that they were less apprehensive. Students then went on to retake their GCSE over Years 10 and 11 in a modular form, although the mathematics department did not encourage retakes of these modular examinations.

This school volunteered five teaching groups for participation in this research, but unforeseen internal school circumstances led to two groups being withdrawn as their response rates were too low to support quantitative analysis. Three sets remained: two borderline sets and one lower grade set (n=48).

School D was a large mixed 11-18 state school with approximately 1650 students. Its catchment area centred on a relatively affluent region lying between two towns. The most recent Ofsted inspection had rated the school as good. Achievement rates were above the national average, and the CVA score was below the national median.

The students at School D were split into two bands and then set within these bands. All students sat a modular examination in GCSE mathematics, taking the initial modules throughout Year 10 and 11 and then sitting their final examination at the end of Year 11. Students were allowed to retake any of the initial modules in order to improve their overall chances. The school volunteered six teaching groups for participation in the research: two borderline sets and four lower grade sets (n=75).

School E was a mixed 11-18 state school with approximately 1150 students. Its catchment area was centred on a relatively affluent area of an urban town. The most recent Ofsted inspection had rated the school as satisfactory. Achievement rates were close to the national average, and the CVA score was below the national median. The cohort studied was split into two bands and then set by ability within these bands.

School E was experimenting with a multipart model of provision. In the first instance, all students sat a modular form of their GCSE mathematics, taking the initial modules throughout Key Stage Four and sitting their final examination at the end of Year 11. Students were allowed to retake any of the initial modules in order to improve their final grades. However, the school was also trialling a system where they entered students for a linear GCSE mathematics examination at the start of Year 11 under a different examination board. This was being done in order to give the students a “double chance” of getting a grade C. The school volunteered five teaching groups for participation in the research: three borderline sets and two lower grade sets (n=73).

The final sample thus consisted of 326 students from five different schools, and from 22 different teaching groups: 195 learners from 11 ‘borderline’ sets and 131 learners from 11 ‘lower grade’ sets.

5.2.2 Questionnaire Design, Pilot, Application and Evaluation

The questionnaire consisted of an adapted version of a pre-existing instrument, the Attitudes Toward Mathematics Inventory or ATMI, used with permission. The ATMI was originally developed for use with high school and college students in America, and consists of 40 items which relate to four affective dimensions: enjoyment, motivation, self-confidence and value (Tapia and Marsh 2004). Each item comprises a statement together with a five-point Likert scale ranging from ‘strongly disagree’ to ‘strongly agree’. Eleven of these items are worded negatively and coded using an inverse scale. Although it is recognised here that Likert scales can implicate certain biases and psychological effects (Abelson and Tukey 1970; Cohen, Manion and Morrison 2011, pp.386-390), the ATMI has produced excellent reliability scores and its four subscales have proven robust under confirmatory factor analysis (Tapia and Marsh 2005); further, it has been positively evaluted against other existing instruments for measuring affect in mathematics education (Chamberlain 2010).

Importantly, the four factors of the ATMI offered good coverage of the localised research questions: ‘value’ speaks principally to how the students view the subject area of mathematics, whilst 'enjoyment', 'motivation' and 'self-confidence' relate to both the learners' views on their own study of mathematics, as well as whether and how they consider themselves to be mathematicians. Further to this some of the items directly explicate opinions on specific goals identified in chapter one; for instance "mathematics is important in everyday life" reports on the respondent's appreciation of how learning mathematics can develop numeracy skills, whilst "mathematics helps develop the mind and teaches a person to think" probes the extent to which the respondent considers mathematics education might develop thinking skills.

The ATMI was adapted for piloting as follows: brief instructions were added to the front page, along with tick boxes for gender and space for the participant's predicted grade; terms and spellings that were specifically American (such as 'math' and 'high school') were anglicised; and two additional qualitative questions were appended to the questionnaire. These asked how the participant felt mathematics might be useful for them in the future, and why they thought mathematics was a 'core' subject in schools; their inclusion was designed to offer a slightly more subtle indication of the participants' attitudes and to facilitate purposive sampling for the second stage of the research. The only significant change to the ATMI items was to two of the 'enjoyment' items. The original items 32 and 33, "I am willing to take more than the required amount of mathematics" and "I plan to take as much mathematics as I can during my education" were considered specific to the American model of schooling, so "I would be willing to attend extra maths lessons" and "I am going to put a lot of effort into my GCSE mathematics" were trialled in their place; although the risk of social desirability bias was noted, it was considered that this would be limited by the confidential nature of the questionnaire.

The adapted questionnaire was piloted in a separate school with a lower attaining group of twelve learners, including two students who did not speak English as their first language and an equal number of each gender. The observed mean scores for the factors were broadly consistent with those reported in Tapia and Marsh (2004). Further, three of the four factors produced excellent values of Cronbach's alpha: for enjoyment $\alpha = 0.911$, for self-confidence $\alpha = 0.812$ and for value $\alpha = 0.922$. For motivation α was calculated as 0.462, but this factor had included the one single-item instance of non-response observed in the pilot, and when a value of '5' was extrapolated from the other items in this factor, α increased to 0.710. This suggested that the low initial value of α for this factor was principally consequent from the sample size and the smaller number of items. The questionnaire took between 15 and 20 minutes to complete as had been predicted.

The participants in the pilot underlined words which they felt were difficult and this led to some further changes to the language used; for instance after four participants failed to recognise the word 'dreaded', the item "mathematics is one of my most dreaded subjects" was reworded as "mathematics is one of the subjects I fear the most". Item 32 was changed again to "if extra maths had been offered as an option subject, I would have chosen it", since it was felt that some participants were taking "extra maths lessons" to refer to revision sessions, as opposed to an additional course of study as implied by the wording of the original ATMI. The opening 'predicted grade' box was replaced with the question 'what set are you in?' as not all students had been clear about their predicted grades and thus this item had become heavily influenced by the teacher. The term "core subject" had also not always been understood, so the final open qualitative question was reworded as "why do you think everyone learns mathematics at school?" Finally, the questionnaire appended an item asking the participants whether they would be willing to opt in to the next stage of the research by taking part in a short follow-up interview. A complete copy of the final questionnaire is provided in Appendix D.

Where possible, the questionnaire was administered in person by the researcher, visiting each group in the context of their mathematics lessons; students who decided to opt out or who had completed their work could then proceed with their regular work. In cases where a direct visit was not possible or deemed inconvenient by the school, a short sheet of instructions was produced, including a script for the supervising teacher; this was primarily an issue with school C where the completion of the questionnaires were organised on site by the head of department. The provision of an instruction sheet was intended to ensure that each teacher would briefly outline the purposes of the research and inform the participants that their responses were confidential.

After collection, the questionnaire data was coded and analysed using SPSS. All t-tests described in section 5.3 assumed equal variances of the data sets; this assumption was supported in all cases but one by applications of Levene's test. The exception was the comparison of the mean values of the motivation factor as calculated for the borderline and lower grades learners (section 3.5.2); however this was a marginal case and the removal of the assumption made no difference to the reported result. A Shapiro-Wilk test was applied to the total ATMI score data and rejected the null hypothesis that it was normally distributed (statistic = 0.987, df =326, p=0.005); in light of this no t-tests were carried out between subgroups smaller than the size of each school's sample, as these might fall short of fulfilling the assumptions of the t-test procedure.

5.2.3 Interview Design, Application and Analysis

A follow-up interview tool was selected to complement the questionnaire, so as to challenge the preliminary conclusions and strive for deeper understanding in line with the practices of grounded theory (Glaser and Strauss 1967). The biographic-narrative nature of the interviews supported the use of a semi-structured format (Wengraf 2001, p.5), since a semi-structured interview has the potential to afford the participant agency to construct an authentic narrative which foregrounds their experiences and subjective beliefs, whilst still addressing the research questions, limiting researcher bias, and providing preliminary structure for the subsequent comparisons and analysis.

A set of three questions with follow-up prompts was constructed and is reproduced below in section 5.4. The interview questions were planned not only to revisit the content of the questionnaire but also to integrate the more personal, individual experiences of the participants, being mindful of the first global research question. Additional questions or shifts of emphasis were added onto the interviewer's prompt sheet whenever a participant had written something considered particularly salient or unusual.

A purposive sample was constructed using the quantitative data (Cohen, Manion and Morrison 2011, pp.156-7). Six learners who were considered together to be representative in terms of demographics and responses were chosen for interview out of the volunteer participants from each centre: two from borderline sets, two from lower grade sets, and two in reserve in case of pupil absence; further details of this process are offered in section 5.4. In total twenty interviews were conducted, ranging in length from four and a half to fourteen and a half minutes. After transcription, the interview data were analysed and sorted in a manner similar to that described in section 3.3.3, that is drawing on the phenomenographic tradition (Marton 1994) by producing broad categories which described how the learners had reported experiencing the teaching and learning of mathematics. The move towards theoretical saturation (Glaser and Strauss 1967) at this stage of the thesis as a whole meant that this process drew heavily on categories which had arisen from the previous components of the research. Coding which followed the local research questions was developed, and two new categories with potentially synoptic concerns were appended: "deferring purpose, possibly for psychological advantage" and "fixed/incremental beliefs about intelligence". 'Questioning' was also appended as a sub-category within "pedagogy and perceptions of legitimate participation in communities of practice".

5.2.4 Ethics

This research was designed and carried out in line with university guidelines regarding ethical research (the relevant ethics form is reproduced in Appendix E). To this end, measures were taken at each stage to involve, respect and protect the participants. Only students from Year 10 were included in this research to minimise any possible negative impact from taking time away from their mathematics lessons. It was intended and planned that all questionnaire participants were informed, either by me or their class teacher, of the purposes of the research in terms designed to be easily understood, so that all learners could either give informed consent or opt out and carry on with their school mathematics work. They were also given the chance to ask any questions after the questionnaires had been completed, in line with the ethos of critical research. For at least some classes this occasion was used by the class teacher as a learning opportunity where the students were involved in a discussion about how some of the skills they had been practising in class, such as questionnaire design and measuring correlation, might herein be applied. All of the participants selected for the interview stage were given a second chance to opt out when they were informed that they had been chosen.

All physical copies of the data were handled and stored securely at all stages. Questionnaires where the student had not volunteered for interview were instantly anonymous, and blanket anonymity was secured after collation for the electronically stored data when both the questionnaire responses and interviews were classed using a system of four digit codes.

Participating schools were also protected: the research was fully explained to centres before commencement; identifying features have been removed or disguised in this report to support anonymity; centres were given the chance to preapprove the selection of learners before the interview stage; and after the research had been completed each centre received a personalised report of the key findings so that they might consider how the research could benefit them and inform their own future practice.

5.2.5 Validity and Reliability

Whilst it has been previously noted in section 2.5.3 that the notions of validity and reliability are variously understood within critical paradigms of research, a number of practical steps were taken to bolster claims of validity and reliability for this research. In the first instance, the use of a pre-evaluated quantitative instrument, with minor changes checked through piloting, co-opts a number of claims. Tapia and Marsh (2004) demonstrate content validity of the ATMI through detailed factor analysis, and assert test-retest reliability after a four-month follow up resulted in a Pearson correlation coefficient of 0.89 for the total scale. They also report high values of Cronbach's alpha, supporting claims of internal consistency and reliability; this statistic was recalculated for each factor in this sample with the following results (n=326): for enjoyment $\alpha = 0.874$ on 10 items; for motivation $\alpha = 0.729$ on 5 items; for self-confidence $\alpha = 0.936$ on 15 items; and for value $\alpha = 0.850$ on 10 items. Whilst the meaning of this statistic can be variously construed (Field 2009, pp.675-6) these values are conventionally considered excellent indicators of reliability.

The use of interviews further increased the validity of this research, as participants' meanings could be verified and issues explored in a qualitative manner so as to develop the convergent validity of this research. The transcripts were checked and double checked to support consistency and reliability, and the semi-structured nature of the interview served to support both regularity in the data collection stage, and the appraisal of validly comparable responses in the analysis stage.

It is not claimed here that the quantitative results of this research are strictly generalisable. Nevertheless, the steps taken herein to ensure that the sample involved a range of schools, and the purposive sampling of participants for interview, do support the claim that the broad findings of this research have relevance beyond their immediate context, in resonance with the sense of generalisability argued for in section 3.3.5.

5.2.6 Literacy and Language

In a similar manner to chapter three, and in consonance with the discussion of section 3.3.7, minor edits have been made when presenting quotes in the subsequent sections. Predominantly, the speech patterns of the Year 10 students interviewed in this research contained a number of fillers, and it was felt that these could be distracting and unhelpful to the reader. For instance, section 5.4.1 includes the following quote:

"… the thing is, algebra and things… you don't really need that in life, do you really?"

The corresponding excerpt from the original transcript reads as follows:

"'.. the thing is like, algebra and things like you don't really need that in life, do you really?"

The full quote includes two uses of the filler 'like'. The first use was considered to signal most likely a pause for thinking, then less probably intent on the part of the speaker to slightly alter the stress within the sentence. It was felt that neither of these implementations would qualitatively alter the semantic content of the sentence, so the first 'like' was removed. The role of the second usage of 'like' was less clear; instead of functioning as a filler, the ‘like’ could be construed as denoting an incomplete thought, such as *“algebra and things like* (that)*”*; this could be argued to shift slightly the nuance in the sentence, so the second ‘like’ was removed but replaced with an ellipsis, in an attempt to maintain the integrity of the source material. In light of these changes, no linguistic or syntactic analysis which would be compromised by such changes has been conducted on the reported qualitative data. Further, other idiomatic speech patterns and vocabulary have typically been retained.

5.2.7 Researcher as Instrument

My personal context of learning GCSE mathematics was both very different and very similar to those described here; my experiences of learning mathematics in a ‘top set’ meant I was largely exempt from concerns about borderline qualification, yet much of my GCSE mathematics learning involved practice-centred pedagogy similar in many respects to that which is described by the learners in this chapter. More immediately though, my experiences of teaching GCSE mathematics to students in similar cohorts meant that I was at risk of introducing substantial researcher bias, and it is recognised here that a conscious effort was made neither to assume these learners would be similar to those whom I had encountered before, nor to judge negatively teachers whose pedagogic choices and actions were qualitatively different to my own previous approach as a class teacher. Although many of the findings of this chapter should be understood as being broadly in line with my own personal beliefs about teaching and learning, it is held that the convergence of the quantitative and qualitative data, the accord between these findings and the results of the previous chapters, plus the unexpected nature of some of the results speak to the legitimacy of the research.

5.3 Questionnaire Results

This section summarises the results of the questionnaire. Section 5.3.1 presents the overall results of the ATMI, section 5.3.2 compares the combined ATMI results of the two cohorts and section 5.3.3 compares the combined ATMI results of male and female learners. Section 5.3.4 goes on to present and compare the ATMI results for each centre, including breakdowns by cohort, gender and teaching group. Finally, section 5.3.5 offers a summary of the qualitative data obtained from the two open-ended questions at the end of the questionnaire.

5.3.1 Overall Results of the ATMI

Each of the 40 items on the ATMI is scored on a five point scale from a strongly negative score of 1 to a strongly positive score of 5. This gives the ATMI a theoretical range of 40 points to 200 points; a totally neutral response would result in a score of 120 points. Tapia and Marsh (2004) reports a mean score for American high school students (n=545) of 137.36, and a standard deviation of 28.93.

As a whole (n=326) the total scores of the Year 10 students ranged from 66 to 184, although the two joint lowest scores of 66 qualified as outliers; the mean score was 129.86 and the standard deviation was 23.24. (Whilst this is somewhat lower than that reported in Tapia and Marsh (2004), this difference could be understood as being consequent of the anglicisation of the tool.) Exactly five students (1.5%) recorded the ‘neutral’ score of 120; 106 students (32.5%) achieved a ‘negative’ score below 120; and 215 students (66.0%) achieved a 'positive' score above 120. The total scores are summarised in figure 5.1 below.

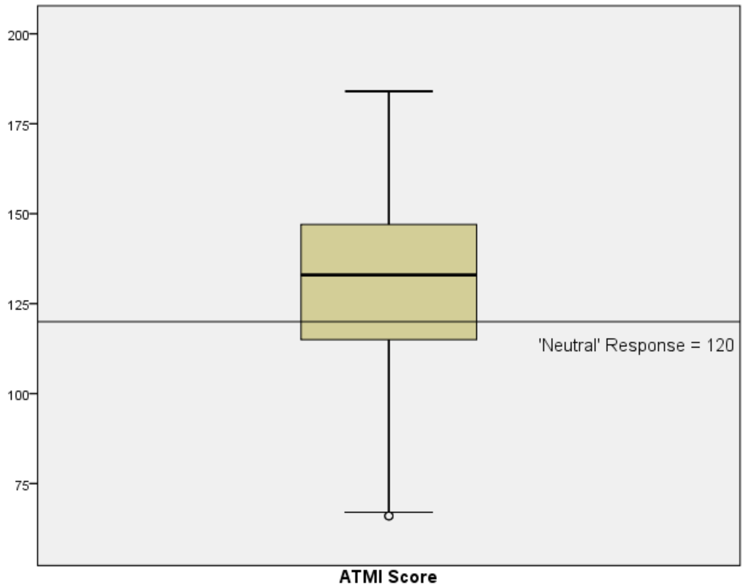


Figure 5.1: Total Scores on the ATMI for the Entire Sample (n=326)

The overall results for each factor over the entire sample are summarised in table 5.1, with the results reported in Tapia and Marsh (2004) in the shaded columns.

Factor	Number of Items	'Neutral' Score	Mean	Standard Deviation	Mean per Item	Reported Mean	Reported Mean per Item
Enjoyment	10	30	28.74	7.14	2.87	31.91	3.19
Motivation	5	15	15.80	3.32	3.16	15.99	3.20
Self-confidence	15	45	47.88	11.20	3.19	51.10	3.41
Value	10	30	37.44	5.47	3.74	38.37	3.84

Table 5.1: Factor Scores on the ATMI for the Entire Sample (n=326)

It should be recognised that the differences between factors are, at least in part, artefacts of the instrument; the results of Tapia and Marsh (ibid.) yield means per item with the same ranking of factors. However, whilst the minor differences in the instrument used prohibit formal quantitative comparisons, it is suggestive that the disparity between factors was greater than expected in the current results, that the mean score for ‘enjoyment’ is in fact below the ‘neutral’ score, and that the mean score for ‘value’ is markedly higher than the ‘neutral’ score.

A summary of the results for each item is presented in table 5.2, indicating the percentage of students that selected each box, where 1 is the most negative response (typically ‘strongly disagree’) and 5 is the most positive response (typically ‘strongly agree’). The symbol * denotes an inverted scale item. All figures are rounded to the nearest percent.

Item	ENJOYMENT	1	2	3	4	5
3	I get a great deal of satisfaction out of solving a mathematics problem.	9	20	40	28	4
24	I have usually enjoyed studying mathematics in school.	11	28	38	19	4
25*	Mathematics is dull and boring.	20	23	32	21	5
26	I like to solve new problems in mathematics.	8	23	35	32	2
27	I would prefer to do work in maths that to write an essay.	7	18	18	39	18
29	I really like mathematics.	23	27	31	15	4
30	I am happier in a maths lesson than in any other lesson.	26	40	25	6	3
31	Mathematics is a very interesting subject.	17	25	34	23	2
37	I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in maths.	4	16	36	38	5
38	I am comfortable answering questions in maths lessons.	7	15	27	44	7
	MOTIVATION					
23	I am confident that I could learn more difficult mathematics in the future.	4	20	24	48	4
28*	I would like to avoid using mathematics in college or sixth form.	9	28	32	28	3
32	If extra maths had been offered as an option subject, I would have chosen it.	17	33	21	23	5
33	I am going to put a lot of effort into my GCSE Mathematics.	0	1	12	56	30
34	The challenge of maths appeals to me.	7	29	43	20	2

	SELF-CONFIDENCE					
9*	Mathematics is one of the subjects I fear the most.	12	24	26	32	6
10*	My mind goes blank and I am unable to think clearly when working with mathematics.	10	24	27	31	8
11*	Studying mathematics makes me feel nervous.	3	14	27	45	11
12*	Mathematics makes me feel uncomfortable.	5	14	20	45	16
13*	I am always under a terrible strain in maths lessons.	4	15	22	43	15
14*	When I hear the word mathematics, I have a feeling of dislike.	15	23	27	27	8
15*	It makes me nervous to even think about having to do a mathematics problem.	3	14	21	49	13
16	Mathematics does not scare me at all.	6	21	26	33	14
17	I have a lot of self-confidence when it comes to mathematics.	9	27	40	19	4
18	I am able to solve mathematics problems without too much difficulty.	6	19	41	32	2
19	I expect to do fairly well in maths.	5	20	29	42	5
20*	I am always confused in my mathematics lessons.	6	15	30	42	7
21*	I feel a sense of insecurity when attempting mathematics.	2	17	28	45	9
22	I learn mathematics easily.	12	24	36	26	3
40	I believe I am good at solving maths problems.	7	20	42	29	2
	VALUE					
1	Mathematics is a very worthwhile and necessary subject.	3	5	18	53	22
2	I want to develop my mathematical skills.	0	2	18	61	20
4	Mathematics helps develop the mind and teaches a person to think.	1	6	29	55	9
5	Mathematics is important in everyday life.	1	9	18	50	22
6	Mathematics is one of the most important subjects for people to study.	1	10	20	50	19
7	Studying GCSE mathematics will be helpful no matter what I go on to do at college or in sixth form.	2	5	21	49	24
8	I can think of many ways that I use maths outside of school.	2	11	30	46	11
35	I think studying advanced mathematics is useful.	4	18	33	42	4
36	I believe studying maths helps me with problem solving in other areas.	1	11	28	54	7
39	Being good with maths could help me in jobs in the future.	0	1	13	56	29

Table 5.2: Summary of ATMI Results by Item

Any analysis of results at the level of individual items incurs a risk of methodological biases. Notwithstanding, together these results facilitate an initial response to the localised research questions.

How do the learners view the subject area of mathematics?

The sampled students in Year 10 view mathematics as worthwhile (item 1) and an important part of their schooling (item 6). They have a strong sense of the value of mathematics, and almost three quarters of them agree that mathematics can inculcate an everyday numeracy (item 5,) even if some of these learners do not recognise mathematics as immediately in their own lives (item 8). They are also aware of other goals of mathematics education, including supporting workplace practices (item 39) and, to a lesser extent, developing thinking skills (items 4 and 36). To this end, the students from the borderline and lower grades sets strongly want to develop their mathematical skills at the moment (items 2 and 33). However, they are less convinced by the prospect of studying advanced mathematics (item 35) to the extent that approximately one third would actively seek to avoid studying it in the future (item 28).

How do the learners view their own study of mathematics?

Despite their strong sense of the value of mathematics, very few students reported a strong liking for mathematics (items 29 and 30); typically only a quarter of students find lessons enjoyable or interesting (items 24 and 41) whilst half find them dull and boring (item 25). Most students prefer other lessons (item 30) although curiously the students as a whole do prefer mathematics work to essays (item 27). In summary it appears that these students view their study of mathematics as important and valuable, but not necessarily enjoyable.

How do the learners position themselves with respect to the practice of mathematics?

Although approximately half of the students said that they felt confident answering questions and expressing their own ideas (items 37 and 38,) a core of about one quarter of the students expressed low self-confidence. For these students, mathematics is one of the most feared subjects (items 9 and 16) and in lessons they find themselves unable to think clearly (item 10) and are confused and insecure (items 20 and 21). It is striking that 38 per cent of students agreed or strongly agreed with item 14, “when I hear the word mathematics, I have a feeling of dislike.” Whilst every learner’s mathematical identity and identity-making processes are unique, it is plausible that simultaneously considering mathematics as valuable, difficult and stressful might typically lead to some learners developing identities of marginal participation and strategic compliance.

The brief discussions above have already highlighted the existence of different trends within the reported affective profiles. The following sections will go on to explore whether and how these trends might be related to the demographic characteristics and school experiences of the learners.

5.3.2 Comparisons between Borderline and Lower Grade Students’ Scores

The total ATMI scores of students in borderline groups (n=195) ranged from 66 to 184, with a mean of 133.01 points and a standard deviation of 23.85 points. The scores of students in lower groups (n=131) ranged from 66 to 181, with a mean of 125.18 points and a standard deviation of 21.55 points. The difference of 7.83 points between means was highly statistically significant (t=3.019, df=324, p=0.003) and suggests that, although a similar range of attitudes can be observed in both cohorts, in general students in lower grade groups possess a somewhat less positive attitude towards mathematics than their peers in borderline groups. This finding is further supported by considering the location of the quartiles and the overall distribution as represented in figure 5.2 below.

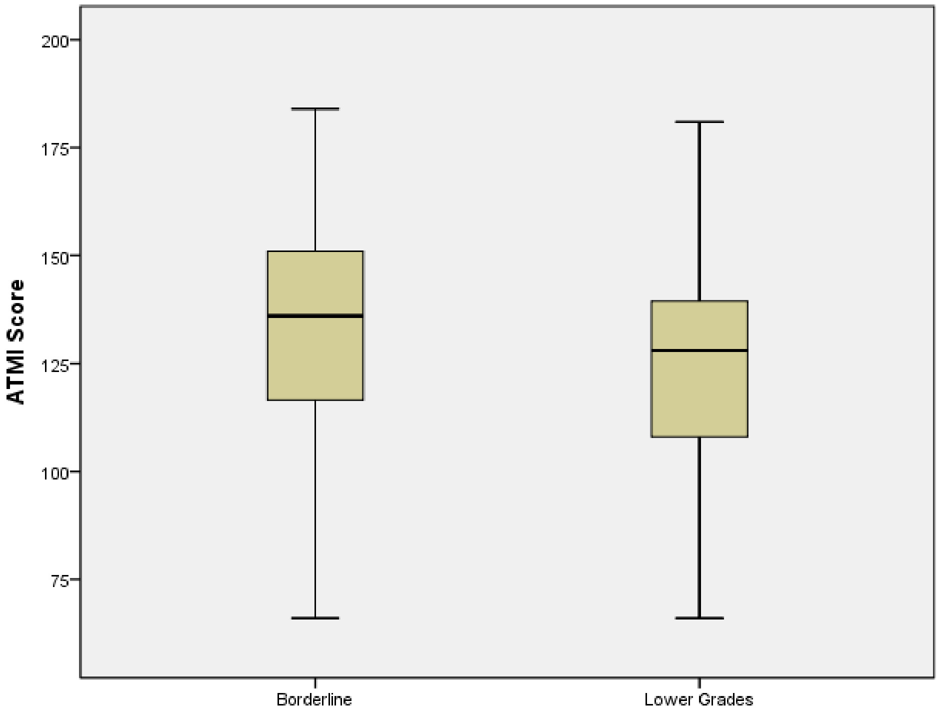


Figure 5.2: Distributions of Total ATMI Scores for Students in Borderline and Lower Grade Teaching Groups

The differences between the overall scores for affect can be understood further by considering the individual factors. Table 5.3 overleaf presents the mean scores of each factor reported by each cohort; the standard deviation of each result is offered in brackets. All reported differences were statistically significant: for enjoyment $t=2.599$, $df=324$, $p=0.010$; for motivation $t=2.203$, $df=309.4$, $p=0.023$; for self-confidence $t=2.901$, $df=324$, $p=0.004$; for value 2.119, $df=324$, $p=0.035$.

Factor	Borderline	Lower Grades	Difference	Difference Per Item
Enjoyment	29.57 (7.40)	27.50 (6.57)	2.08	0.208
Motivation	16.13 (3.52)	15.31 (2.93)	0.82	0.164
Self-confidence	49.34 (11.13)	45.71 (11.00)	3.63	0.242
Value	37.96 (5.25)	36.66 (5.72)	1.30	0.130

Table 5.3: Mean Factor Scores and Differences by Cohort

Whilst the differences per item for each factor are comparable, the results do offer that the generally higher affective profile of borderline learners is perhaps more consequent from greater self-confidence and enjoyment than from a larger appreciation of the value of mathematics.

5.3.3 Comparisons between Male and Female Students' Scores

Gender has been recognised as relevant when studying affect in mathematics education (for instance Walkerdine 1998) and has further been shown to be salient in the development of mathematical identities (Solomon 2007b). In light of this, gender comparisons were carried out as part of the analysis. The total ATMI scores of male students (n=161) ranged from 66 to 184, or from 79 to 184 if three outliers were excluded from the range. Male students attained a mean ATMI score of 133.87 points and a standard deviation of 22.57 points. The scores of female students (n=165) ranged from 67 to 184, with a mean of 125.95 points and a standard deviation of 23.28 points. The difference of 7.92 points between means was highly statistically significant (t=3.119, df=324, p=0.002), supporting a general claim that whilst male and female students report a similar range of attitudes towards mathematics, on balance male students display a more positive affective profile than female students. This conclusion can also be inferred from the overall distribution of the scores of both genders, presented in figure 5.3.

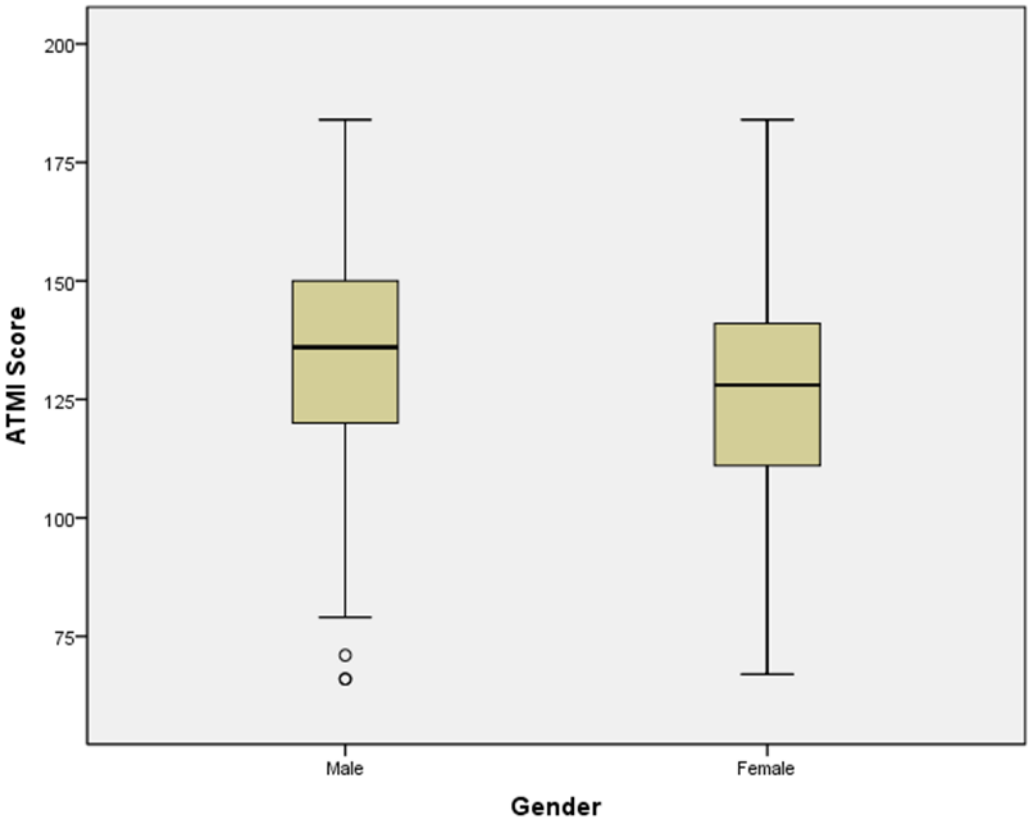


Figure 5.3: Distributions of Total ATMI Scores for Male and Female Students

A two-way analysis of these scores by gender and factor is summarised in table 5.4 overleaf; the differences in enjoyment (t=2.870, df=324, p=0.004) and self-confidence (t=3.400, df=324, p=0.001) were found to be significant, whilst those for motivation (t=1.696, df=324, p=0.091) and value (t=1.499, df=324, p=0.135) were not.

Factor	Male	Female	Difference	Difference Per Item
Enjoyment	29.88 (6.84)	27.63 (7.28)	2.25	0.225
Motivation	16.12 (3.20)	15.50 (3.41)	0.62	0.124 (Not significant)
Self-confidence	49.98 (10.73)	45.83 (11.30)	4.15	0.277
Value	37.89 (5.69)	36.99 (5.23)	0.91	0.091 (Not significant)

Table 5.4: Mean Factor Scores and Differences by Gender

It is noted that the two factors which display significant differences in this gender comparison are also those which gave rise to the largest differences when the data of the two cohorts was considered (see table 5.3); in both cases differences in affect appear to be more strongly associated with personal traits than with more general perceptions of mathematics as a subject. This could be understood as being indicative of a relatively stable appreciation of some of the purposes of mathematics education.

Gender and cohort were evaluated as statistically independent variables (χ^2 = 0.002, df=1, p=0.965, continuity correction used) which suggested that the drops in affect measured between cohorts and genders had the potential to be compounded. Evidence for this was found through a comparison the ATMI scores of male borderline learners and female lower grade learners which established a highly significant mean difference of 15.73 points (t=4.437, df=162, p<0.001). A graphical representation of the full two-way classification is offered in figure 5.4 overleaf.

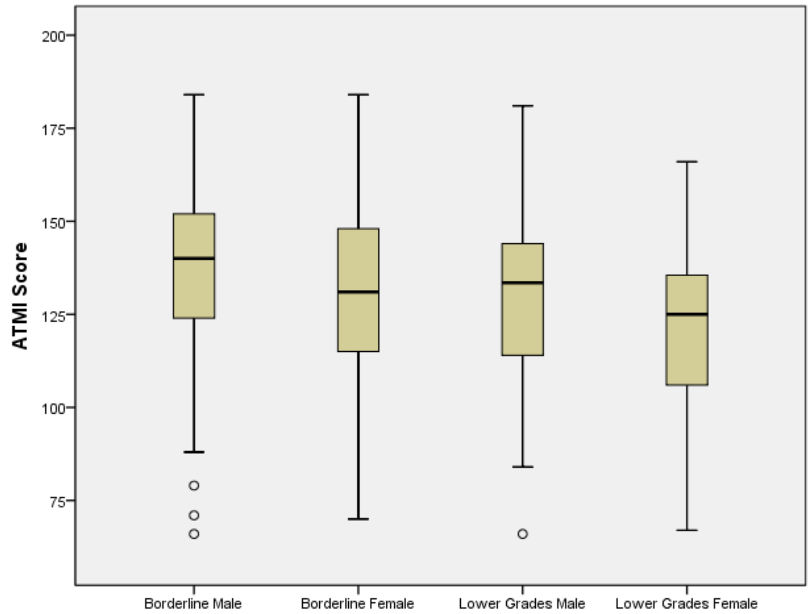


Figure 5.4: Distributions of Total ATMI Scores Subdivided by Cohort and Gender

In summary, the trends in the data have pointed towards net attitudinal differences associated with both gender and ability grouping, such that male students typically reported higher scores than female students, and students in borderline sets typically reported higher scores than their peers in lower grade sets. These differences were observed to have the potential to accumulate. The factors within the ATMI most attendant to these differences were ‘self-confidence’ and ‘enjoyment’, whereas the ‘value’ factor was consistently the most stable.

It has been suggested above in section 5.3.1 that when students hold the value of mathematics in high regard, but do not enjoy its study and have low self-confidence as mathematicians, they might construct marginal mathematical identities. If this is indeed the case, these findings are particularly striking, as they suggest that female learners in lower grade sets are at a substantially increased risk of positioning themselves outside of legitimate practice.

5.3.4 Results of Individual Schools and Teaching Groups

The questionnaire results exhibited substantial differences both between and within schools. Figure 5.5 summarises the distributions of the overall ATMI scores across the five schools; the mean ATMI score and associated standard deviation for each school are then presented in table 5.5 overleaf.

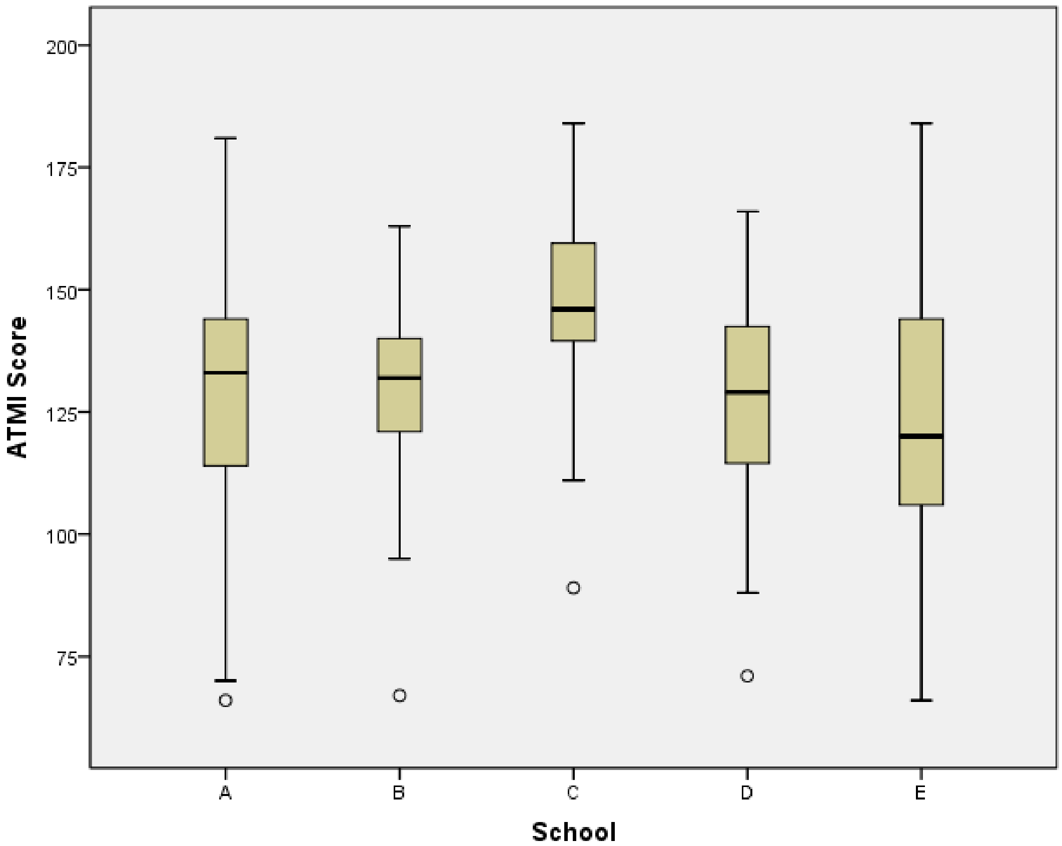


Figure 5.5: Distributions of Total ATMI Scores Subdivided by School

The results in figure 5.5 and table 5.5 immediately highlight that the results for school C are somewhat higher than those of the other schools. Without denying either the potential validity or import of this result, it is recognised this might have arisen in a number of ways: the proportion of borderline learners in school C's sample is relatively high and this might have skewed the data in light of the findings of section 5.3.2; equally, the questionnaires in school C were not administered directly (see section 5.2.2) and this may have unduly steered the results. These concerns are considered further in section 5.3.4.3, but are offered here first to recognise possible limitations.

	Number of Participating Students	Mean Total ATMI Score	Standard Deviation
School A	81	128.98	23.59
School B	49	130.08	18.70
School C	48	146.35	17.04
School D	75	127.23	20.08
School E	73	122.55	27.17

Table 5.5: Summary Statistics of ATMI Scores for each School

In order to facilitate more detailed and careful analysis, the results of each participating school will now be presented and discussed in turn. Each table below contains the mean results, with respective standard deviations given in brackets and both figures rounded to one decimal place. The bracketed letters next to the teaching group labels demonstrate the expected grades of each group as understood during the planning stage; groups labelled C, D or CD were considered 'borderline' in analysis whilst groups labelled DE, DEF, EFG or D-G were designated 'lower grades'.

5.3.4.1 School A

The results of school A are presented in table 5.6.

	Enjoyment	Motivation	Self-confidence	Value	ATMI Total
Overall	28.5 (7.4)	16.0 (3.3)	46.8 (12.2)	37.7 (5.0)	129.0 (23.6)
Borderline	29.8 (6.5)	16.1 (3.3)	49.7 (11.1)	37.3 (4.9)	132.9 (22.2)
Lower Grades	26.9 (8.2)	15.8 (3.2)	42.9 (12.7)	38.2 (5.3)	123.8 (24.7)
Group 1 (CD)	30.7 (5.2)	15.9 (2.9)	51.1 (9.5)	37.6 (4.1)	135.4 (19.1)
Group 2 (CD)	31.7 (5.0)	16.8 (2.6)	54.2 (7.6)	38.5 (4.7)	141.2 (15.7)
Group 3 (EFG)	26.3 (9.2)	15.4 (3.6)	40.0 (11.9)	37.3 (4.2)	119.0 (24.8)
Group 4 (CD)	26.7 (8.0)	15.5 (4.5)	43.3 (13.3)	35.7 (5.5)	121.2 (26.9)
Group 5 (EFG)	27.4 (7.5)	16.2 (2.9)	45.8 (13.1)	39.0 (6.2)	128.3 (24.5)
Male	29.8 (8.0)	16.1 (3.7)	49.4 (12.8)	37.9 (5.3)	133.2 (26.3)
Female	27.3 (6.6)	15.9 (2.8)	44.2 (11.1)	37.5 (4.8)	124.8 (20.0)

Table 5.6: Mean Results for School A (n=81)

In many ways the results of school A are typical of the data set as a whole; the overall figures are similar to those reported in the previous general analysis, with differences between gender groups and ability groups mostly similar to those already noted. Nevertheless, there are some minor variances: for instance, between the borderline and lower grade students the difference in self-confidence is more pronounced than expected, and the lower grade students actually report a slightly higher measure of value than their borderline peers.

Against this background, the results at the level of the teaching groups display a more striking feature. School A separated its students into two bands for setting, and whilst the results of the band containing groups 1, 2 and 3 follow the expected trend, groups 4 and 5 in the second band seem to reverse it; the mean responses for each factor on the ATMI from the lower grade group 5 noticeably exceed those of the borderline group 4. Comparisons between groups 1, 2 and 4, and also between groups 3 and 5 illustrate how similarly set teaching groups from different bands can report significantly diverse responses. Although these differences are undoubtedly due in part to the characters of the individual students involved, these findings together are consonant with the finding of Hallam and Deathe (2002), namely that setting does not have a consistent impact, but that instead its influence is mediated by individual teachers.

5.3.4.2 School B

The results of school B are presented in table 5.7 overleaf. As was the case with school A, the results of school B are largely reflective of the overall trends, incorporating expected differences between cohorts and genders. However, there were at least two notable divergences. First, the scores for the self-confidence factor were approximately two or three points higher than the average, and this difference seemed relatively consistent across both cohorts and genders. Since school B had a strong reputation for academic success, this might be understood as being indicative of a slightly heightened general academic self-concept. Second, the overall mean result of 'value' was the lowest reported by any of the five schools. Consideration of the figures suggests that this is primarily consequent from the very low score for value reported by teaching group 8.

	Enjoyment	Motivation	Self-confidence	Value	ATMI Total
Overall	28.2 (6.2)	15.7 (2.8)	50.4 (8.8)	35.7 (5.4)	130.1 (18.7)
Borderline	29.2 (6.9)	16.7 (3.0)	51.5 (8.4)	38.0 (4.4)	135.4 (18.5)
Lower Grades	27.7 (5.7)	15.1 (2.6)	49.8 (9.0)	34.4 (5.6)	127.0 (18.4)
Group 6 (CD)	29.2 (6.9)	16.7 (3.0)	51.5 (8.4)	38.0 (4.4)	135.4 (18.5)
Group 7 (DE)	29.3 (4.5)	16.0 (2.5)	51.9 (5.7)	37.1 (4.7)	134.3 (13.6)
Group 8 (EFG)	25.3 (6.6)	13.9 (2.3)	46.9 (12.0)	30.8 (4.6)	116.9 (20.0)
Male	29.0 (6.6)	16.2 (2.7)	53.5 (7.7)	35.2 (6.0)	133.9 (19.2)
Female	27.6 (5.8)	15.3 (2.9)	47.7 (8.9)	36.2 (4.9)	126.7 (18.0)

Table 5.7: Mean Results for School B (n=49)

Indeed group 8 offered particularly low scores for every factor, and reported the second lowest mean ATMI total for any teaching group in this research. Conversely group 7, despite being considered a 'lower grade' group, reported very similar scores to the ‘borderline’ group 6, such that their mean ATMI totals were only 1.1 points apart. Whilst all of these findings could be interpreted as further evidence of individual influences, it could be argued that many of group 7, expected to get grades D and E, view their mathematical activity as sufficiently close to the borderline to still be legitimate; in practical terms, they might plausibly still attain a C grade at GCSE, so the prevalent discourse regarding the import of this gatekeeper qualification would not demotivate them in the same way as students aiming for F and G grades. This argument also speaks critically to the methodology of this research, illustrating the limitations of dichotomous labelling.

5.3.4.3 School C

The results of school C are presented in table 5.8 overleaf; teaching groups 9 and 12 were removed prior to the analysis due to small sample sizes (see section 5.2.1). As shown previously in figure 5.5, the results of school C were appreciably higher than those of the other schools; school C reported the highest mean score both in total and for each of the four factors. The shift implied by this increase is meaningful; an average overall ATMI score of 146.4 is approximately equivalent to offering a neutral response for one-third of the items, then selecting a positive response for the remaining two-thirds. Despite the concerns listed in section 5.3.4, this impressive figure appears genuinely to reflect a higher-than-average affective profile across the school and will now be defended.

	Enjoyment	Motivation	Self-confidence	Value	ATMI Total
Overall	34.2 (6.2)	18.1 (3.0)	53.5 (7.9)	40.6 (3.3)	146.4 (17.0)
Borderline	34.8 (5.9)	18.3 (2.9)	54.2 (7.9)	40.6 (3.4)	147.9 (17.2)
Lower Grades	30.0 (6.5)	16.8 (3.5)	48.5 (6.6)	40.5 (2.7)	135.8 (12.7)
Group 10 (CD)	32.5 (6.1)	16.9 (2.8)	50.6 (7.9)	39.7 (3.4)	139.7 (17.5)
Group 11 (CD)	36.8 (5.2)	19.4 (2.4)	57.1 (6.8)	41.3 (3.3)	154.6 (13.9)
Group 13 (EFG)	30.0 (6.5)	16.8 (3.5)	48.5 (6.6)	40.5 (2.7)	135.8 (12.7)
Male	32.9 (6.5)	17.5 (2.9)	51.4 (9.1)	40.3 (3.8)	142.0 (18.1)
Female	35.4 (5.7)	18.6 (2.9)	55.3 (6.5)	40.8 (2.8)	150.1 (15.4)

Table 5.8: Mean Results for School C (n=48)

The first concern noted in section 5.3.4 was that the prevalence of borderline classes might have unduly influenced the overall distribution of results. This is a definite possibility, as 42 of the 48 learners in the sample were from borderline sets. Notwithstanding, the measured increase appears to affect both borderline and lower grade groups, with the total ATMI score means being higher than the overall results by 14.89 points and 10.62 points respectively. Further support can be marshalled from the data of the three learners from lower grade teaching group 12 who completed a questionnaire; whilst their results were not included in the analysis, their ATMI total scores of 121, 140 and 167 would together suggest a higher than average affective profile.

The second concern noted above in section 5.3.4 was that this collection of questionnaires was not administered under regulated conditions by the researcher, due to practical constraints and out of respect to what was convenient for the school. This might have impacted the data variously, but the main threat to validity is that this change in method could have inflated the results. However, the nature of the increase belies this conclusion; the increase is staggered across the factors and manifests differently in the results of male and female students. The most dramatic difference was in the factor of self-confidence; whilst the mean male score for ‘self-confidence’ was 1.4 points above the equivalent statistic for the combined sample (51.4 points compared to 50.0), the corresponding mean female score was 9.5 points higher than the combined female sample score (55.3 points compared to 45.8), corresponding to a relative extra increase of 8.1 points, or an increase of 0.54 points per item. The second most dramatic difference was for ‘enjoyment’ with an extra increase of 0.48 points per item, then ‘motivation’ with an extra increase of 0.34 points per item, and finally ‘value’ with an additional 0.14 points per item. The combination of these differences meant that school C was the only school where the mean ATMI total score of the female students was higher than that of the male students.

These observations do not entirely negate any possible compromising of the validity of the results for this school, but they do support their inclusion in the research. Moreover, the substantial variation in how these students report an improved affective profile offers some insight into its nature.

The improvement in affect within school C might be explicated as being in part consequent of this school's practice of entering their students for the GCSE twice, in the unusual manner first detailed in section 5.2.1. Each student's first sitting of GCSE mathematics took place at the end of Year 9, prior to the commencement of Key Stage Four. This was ostensibly intended not to boost results, but to provide the school with an assessment benchmark which could then be used formatively; the head of department also suggested that it was intended to familiarise the students with what a GCSE consisted of, so as to assuage some of their concerns about sitting such a high-stakes examination. Although it lies beyond both the scope and intention of this research to establish causative links between assessment models and differences in reported attitudes towards mathematics, this line of argument could elucidate some of the differences noted above. Specifically, since female students typically experience higher levels of both mathematics anxiety and test anxiety (for instance Devine, Fawcett, Szűcs and Dowker 2012), successfully lessening fears about the mathematics GCSE across the school would lead to a more marked increase in affect for female students than for male students, particularly in the areas of self-confidence and enjoyment; these are precisely the changes which have been noted.

5.3.4.4 School D

The results of school D are presented in table 5.9. These were largely aligned with the overall results, with near expected scores for each factor and the ATMI total, plus male students typically attaining higher scores than female students.

	Enjoyment	Motivation	Self-confidence	Value	ATMI Total
Overall	27.4 (6.0)	15.4 (2.7)	47.8 (9.8)	36.6 (5.2)	127.2 (20.1)
Borderline	26.9 (6.7)	15.2 (3.1)	48.5 (10.1)	35.6 (5.8)	126.3 (22.2)
Lower Grades	27.9 (5.3)	15.5 (2.4)	47.1 (9.6)	37.6 (4.5)	128.1 (18.1)
Group 14 (CD)	28.5 (6.8)	15.8 (3.3)	50.1 (11.4)	35.6 (7.3)	130.1 (26.0)
Group 15 (D-G)	29.4 (3.2)	16.6 (2.1)	52.1 (8.6)	39.6 (2.9)	137.6 (12.1)
Group 16 (D-G)	28.9 (5.1)	16.1 (2.0)	45.9 (8.3)	38.6 (5.2)	129.4 (17.4)
Group 17 (CD)	25.2 (6.3)	14.7 (2.7)	46.9 (8.5)	35.6 (4.0)	122.4 (17.6)
Group 18 (D-G)	26.0 (4.4)	14.2 (1.9)	43.9 (8.6)	35.6 (4.3)	119.7 (12.7)
Group 19 (D-G)	27.3 (7.3)	15.0 (2.9)	45.9 (11.3)	36.8 (5.2)	125.0 (23.6)
Male	29.2 (5.0)	15.8 (2.8)	48.2 (9.5)	37.1 (5.9)	130.2 (19.8)
Female	25.4 (6.3)	14.9 (2.6)	47.3 (10.2)	36.1 (4.4)	123.8 (20.2)

Table 5.9: Mean Results for School D (n=75)

The most unusual feature of these results was that, uniquely amongst the schools, here the lower grade groups slightly outperformed their peers in the borderline classes. This is a curious result which appears to contradict the overall trend noted in section 5.3.2. It is however feasible to consider that this counterexample is in part consequent of the construction of the sample from school D. In particular, and following on from the comments in section 5.3.4.2, the decision of the school to consider lower grade sets as ‘D-G’ may have lessened the risk of students in these sets conceptualising their mathematical practice as impossibly far from the borderline.

5.3.4.5 School E

The results of school E are presented in table 5.10 overleaf. Whilst it is proper to note that many students in school E conveyed quite positive attitudes towards mathematics on the questionnaire, it is also the case that school E reported the lowest attitudinal profile in a number of respects. For instance: school E attained the lowest mean ATMI score overall; the lowest mean score for three of the four factors (enjoyment, motivation and self-confidence); and included the teaching group with the lowest mean ATMI total in this research, group 24. Whilst the figures in table 5.10 generally follow the already observed trends relating to gender and cohort, they are as a whole somewhat lower than the results of other schools.

	Enjoyment	Motivation	Self-confidence	Value	ATMI Total
Overall	27.1 (7.6)	14.6 (3.8)	43.8 (12.9)	37.1 (6.5)	122.6 (27.2)
Borderline	27.2 (7.9)	14.9 (3.9)	45.0 (13.2)	38.0 (5.9)	125.1 (27.3)
Lower Grades	26.9 (7.1)	14.0 (3.4)	40.5 (11.6)	34.5 (7.5)	115.8 (26.4)
Group 20 (C)	28.6 (6.9)	15.5 (4.0)	48.8 (12.6)	39.9 (5.1)	132.7 (23.5)
Group 21 (D)	26.7 (8.5)	14.7 (3.9)	44.1 (12.8)	35.8 (6.2)	121.1 (28.5)
Group 22 (EFG)	29.0 (6.4)	15.7 (2.4)	42.5 (11.3)	37.1 (7.2)	124.3 (22.5)
Group 23 (CD)	25.5 (8.6)	14.1 (3.8)	40.4 (13.9)	37.9 (6.2)	117.9 (30.2)
Group 24 (DEF)	23.7 (7.3)	11.5 (3.3)	37.5 (12.3)	30.5 (6.5)	103.1 (28.1)
Male	29.4 (7.3)	15.7 (3.4)	49.5 (11.9)	39.0 (6.0)	133.7 (25.2)
Female	24.8 (7.3)	13.6 (3.8)	38.3 (11.4)	35.1 (6.5)	111.7 (24.8)

Table 5.10: Mean Results for School E (n=73)

In particular, both groups in the second band, groups 23 and 24, report particularly low results. These may have arisen from singular circumstances, or even from the fact that the second band filled in the questionnaire one teaching period after the first band, so the students may have been more tired. However, it is pertinent that the mean total ATMI score of the male students, 133.7 points, is barely different from the overall male mean of 133.87 points reported in section 5.3.3, whilst the mean total ATMI score of the female students, 111.7 points, is considerably lower than the overall female mean of 125.95. The affective factor most marked by this drop is ‘self-confidence’: the overall mean female score for this factor was 45.8 but within this school it is 38.3; this is a difference of 7.5 points, which corresponds to a decrease of 0.5 points on each item.

The way in which the decrease in affect is staggered across genders and factors contrasts neatly with the increase noted for school C in section 5.3.4.3. It is therefore of note that school E was also working with an unusual assessment structure, entering students for modular GCSE mathematics examinations throughout Key Stage Four whilst simultaneously preparing them for a linear GCSE mathematics examination towards the start of Year 11, so as to offer their students a “double chance” to attain a C grade or higher. It could therefore be argued, in furtherance of the discussion of school C’s results, that this model leads to repeated instances of examination anxiety and persistent exposure to a discourse stipulating the necessity of a C grade in mathematics. Hence whilst repeated entry was managed in school C to improve students’ self-confidence, here the policy of overlapping entry might be narrowing the students’ mathematical experience and having the opposite effect.

5.3.4.6 Differences Within and Between Schools

The school-level results have demonstrated a number of affective trends. Although quantitative expectations are complicated by differences between school setting procedures, in the majority of cases the average borderline student reported a higher measure of affect than their peer in a lower grade class, and the average male student reported a higher measure of affect than their female counterpart. Students typically score higher for ‘value’ than they do for ‘enjoyment’, and many continue to report low ‘self-confidence’. Still, the results at the level of the teaching groups repeatedly remind that all of these trends are mediated by local factors, such as the influence of the particular teacher, or a particular class dynamic.

The comparisons between schools have also given rise to some notable exceptions to the main trends which might further explicate the research questions. Most notably, the extreme values extant in the results of schools C and E strongly advocate the potential impact of school-level influences; whilst the observed differences could be variously explicated, the argument presented above regarding the timings of assessments does account for the observed data. School E might therefore be a noteworthy instance where attention to the role of GCSE mathematics as a gatekeeper qualification has directly resulted in a marked negative impact on students’ mathematical identities.

In summary, the quantitative comparisons between centres have presented that students’ views on mathematics and their mathematical learning are not only subject to influences which operate at a general level, but that they are also shaped by mediations at the levels of the school and the individual teaching group. In this way, every Key Stage Four student must make sense of their own mathematical purpose in light of layered discourses.

5.3.5 Responses to the Final Open-Ended Questions

The questionnaire closed with two-open ended questions, asking the participants how they thought mathematics might be useful for them in the future, and why they thought everyone had to learn mathematics. Whilst these results were useful for the process of purposive analysis (see section 5.4) their analysis was not unproblematic: the responses vary in quality and length, contain a number of linguistic ambiguities, and sometimes conflate the two issues being researched. Further, it should be noted that the responses were offered after each participant had completed the questionnaire, such that the immediate exposure to suggestions implicit in the wording of the ATMI could limit the authority of these findings. Notwithstanding, the responses as a whole offer some further insight into how these students read purpose into the study of mathematics.

The responses referenced a number of the goals and roles previously identified in chapter one of this thesis. There were frequent mentions of mathematics being an 'everyday' skill, as well as widespread recognition that mathematics was useful both in getting a job, and in carrying that job out. There were some mentions of mathematics as a thinking or problem solving skill, but these were much rarer.

The mentions of mathematics as an everyday life skill, when expanded, typically involved tasks that centred on money, such as paying bills or shopping. The comments that related to jobs were more diverse. Whilst some were general statements about mathematics being needed for "nearly every" job, a number were more specific and suggested prior consideration, for instance talking about how mathematics was needed to work as a plumber, an electrician, an engineer or a car customizer. Similarly, some students showed explicit awareness of how a C grade in mathematics was required for them to achieve their desired aims, including becoming an art teacher, joining the army, and getting into college; one borderline pupil stated that she needed an A* to become a vet. Some of the comments about the value of the mathematics qualification, even though brief, did include some linguistic markers which could be understood as echoing particular discourses, such as “help in the future”. More than one student expressed the import of the GCSE unequivocally; in the words of one male borderline student, “higher grades better job”.

There was a small number of more critical comments, in the vein of “don’t know” or “it won’t”. Some comments also differentiated between parts of mathematics that were useful and those that were not: “some might not all stuff we learn though”. This demarcation varied in character; for instance whilst one borderline learner noted that “I do not think certain things like algebra are necessary”, a lower grade learner who wanted to go on to complete an engineering diploma argued that “I may need some skills from maths such as angles and equations but the rest I think is quite pointless to my education.” This internal division of mathematics into ‘useful’ and ‘not useful’ components may be related to the similar psychological processes noted in some of the prodigal and undergraduate learners, wherein the process of separating off or devaluing certain parts of mathematics affords some protection to the academic self-concept.

In summary, the qualitative data of the questionnaire were broadly consonant with the quantitative data, suggesting that even whilst the researched students expressed a range of affective profiles with regard to their own mathematical activity, they typically considered mathematics to be a valuable field of study. The subsequent tension between value and enjoyment that some learners thus experience sometimes appeared to result in frustration; one borderline pupil with a low overall ATMI score of 104 offered “mathematics is very useful however it is dull and boring." The foremost purposes of mathematics education inferred from the qualitative data were ensuring numeracy at the level of the individual, preparing learners for industry and employment, and providing a gatekeeper qualification. As was the case with the quantitative data, there was a lesser but extant recognition of the goal of developing thinking skills.

5.4 Interview Results and Analysis

The interviews were conducted individually, and lasted between approximately five and fifteen minutes apiece, depending on each participant's depth of response. Each semi-structured interview comprised three core questions, together with a small number of follow-on questions which were deployed in cases where the interviewee did not address the contained issues without prompting in their answers to the core questions. The three main questions are reproduced below, together with the associated follow-on questions:

- *This project is all about exploring what different pupils in different schools think about learning mathematics at school. In your own words, what do you think mathematics is all about?*

- *Do you think that mathematics is useful in everyday life?*
- *Do you think that mathematics is useful in people's jobs?*
- *Do you think that mathematics is something you will need in the future?*

- *What do you like, and what do you dislike about learning mathematics at school?*

    - *Have you always liked/disliked mathematics?*

- *How do you feel about your GCSE mathematics exam?*

- *What grade do you think you are going to get?*
- *Do you think anything could have changed this outcome?*

In light of both the quantitative analysis and preliminary consideration of the first few interviews, an additional follow-on question asking each learner to reflect on the structure and organisation of their GCSE mathematics exam was appended onto most of the remaining interviews. This was adapted in light of each school's provision, but was typically phrased by asking pupils to consider whether they would advise other schools to follow the mode and timetable of examination followed by their own school.

The interview questions were intended to inform the local research questions of section 5.0.1, both jointly by supporting the construction of a coherent narrative and individually through more specific correspondences. The first interview question focused on the learner's view of mathematics as a subject area, invoking specific goals which the quantitative data had found to be prevalent in the conceptions of the population, and in this way it spoke most directly to the first local research question. Subsequently, the second and third questions were designed to elicit information about both how the learners viewed their own study of mathematics and how they positioned themselves with respect to the practice of mathematics; these latter questions thus informed the second and third local research questions.

A group of participants was selected from the learners who had given permission at the end of the questionnaire to be included in the next stage of the research. Although practical and access limitations meant that it was impossible to fashion a sample which was wholly representative of all potentially salient viewpoints and learning experiences, a purposive sample was created using the results of the questionnaire. In the first instance, six students were selected from each centre: typically one male student, one female student and a backup student from each of the two cohorts being studied. The selection was conducted holistically using the questionnaire responses, so that the overall sample included students from each cohort and each gender with high and low ATMI responses. To move towards theoretical saturation and support convergent validity, additional attention was also awarded to students who had written something or achieved factor scores which appeared to be particularly typical, atypical, or which resonated closely with the underlying research goals of the study. The names of the six students were then passed in advance to the gatekeeper in each school to ensure that there were no ethical or practical reasons that the students should not be included in the sample. The sample was then finalised at the point of interview, with backup students being used in a small number of cases due to student absence. The final sample is presented graphically overleaf in figure 5.6.

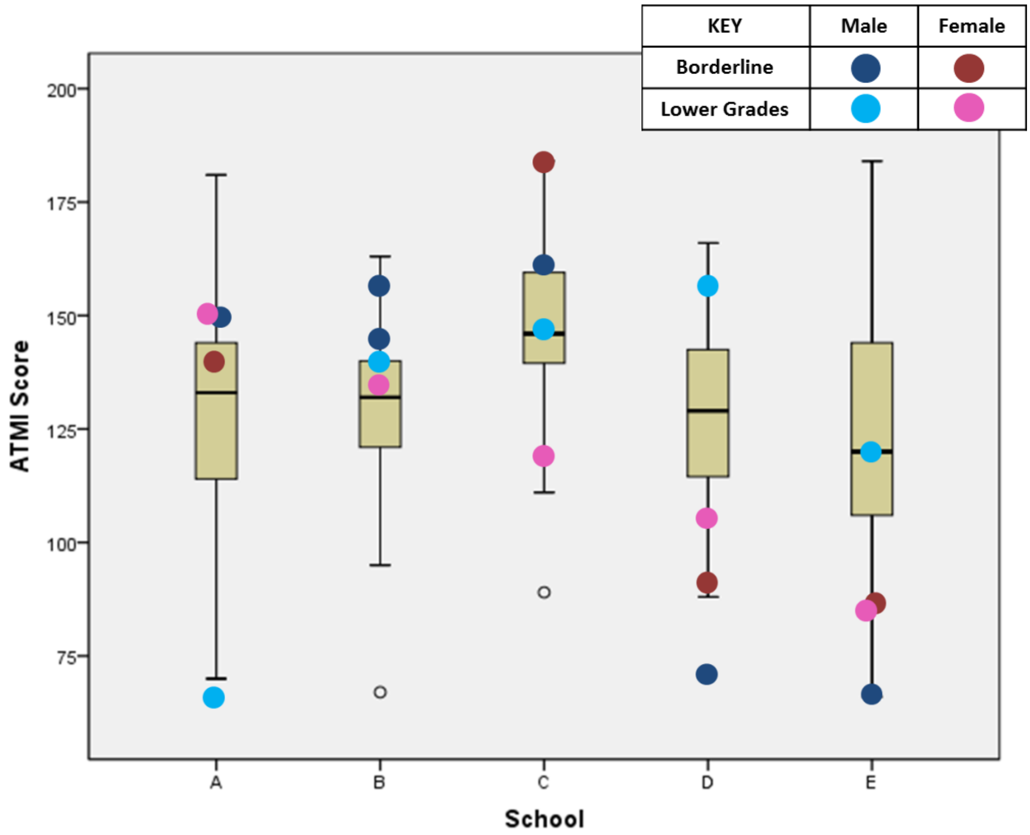


Figure 5.6 Approximate Total ATMI Scores of the Interview Sample against the Observed Distributions of Each Centre

5.4.1 Students' Understanding of the Purposes of GCSE Mathematics

Whilst the participants inevitably communicated a range of perspectives on the purpose of learning mathematics at school, the initial open question "what do you think mathematics is about?" produced a number of consonant responses. Many answers focused on what might be considered to be numeracy; of the twenty interviewed students, seven referred to 'everyday' or 'day to day' use of mathematics without prompting, eight referred to 'numbers' or 'sums' in their initial response, and six mentioned dealing with money. Eight participants also referred in their first responses the aim of preparing learners for the workplace, or mentioned how mathematics might be used in a particular job. Conspicuously, six of the students implied that mathematics was a subject whose utility had not yet been realised, for instance offering that mathematics would be useful ‘later on in life’, or ‘when you’re older’:

"I don't really use maths out of our maths lesson… maybe it will be more useful in the future?'(borderline student)

Two interviewees explicitly recognised in their initial statements the role of mathematics as a gatekeeper to opportunities in education and employment; other purposes such as the development of thinking and problem solving skills, or the support of science education were only occasionally touched upon by individuals. Finally, two students reacted to this question with a leading negative comment, one declaring that mathematics was ‘rubbish’, and the other opining that it was ‘boring’. Overall, the initial responses of the interviewees were broadly convergent with the questionnaire data reported in section 5.3.5, foregrounding the goals of inculcating an ‘everyday’ numeracy, preparing learners for employment, and including an awareness of the role of mathematics as a gatekeeper subject. These intentions were explored further and are considered here in turn.

The first goal of mathematics education considered via the follow-up questions was the intention to equip learners with mathematics that they might need in day to day living. Whilst most of the students interviewed concurred that school mathematics involved skills which were involved in everyday life, both their cognisance of this usefulness and their ability to provide specific examples varied significantly. As has already been noted, interviewees from both groups of learners commonly invoked scenarios involving shopping or money. For instance:

"...mostly every day you have to go to a shop or pay for something – that's using maths." (lower grades student)

"'Only counting money, really. I think that's all I use it for, like, outside of school... make sure you get the right change and stuff."(borderline student)

A few students offered examples beyond financial applications; these included contexts such as reading the time, measuring out lengths of wood, and considering grid references and distances when planning a bike ride. Conversely, and in spite of the prevalent agreement with the 'everyday mathematics' discourse, some students found it difficult to offer or construct concrete instances where they might use mathematics in the real world. In particular, one borderline pupil claimed at the start of the interview that mathematics was about "things that need to be calculated which… are used in everyday life", yet did not manage to offer a single example, even with prompting.

Not every student was entirely convinced about the utility of mathematics in everyday life. One learner, who was in a lower grades set, said that she didn't think that mathematics was useful in everyday life. Further, two other learners at this point actually used the notion of utility to criticise parts of the curriculum; these comments were consonant with the divisions of mathematics into 'useful' and 'not useful' noted above in section 5.3.5:

"...we were just doing factorisation and stuff in maths and it was just annoying me that we had to learn it when I don't think it's going to come in useful..." (borderline student)

"…the thing is, algebra and things… you don't really need that in life, do you really? …if you want to become a maths teacher you might to… but I don't see the point…" (lower grades student)

Algebra was a popular choice of students arguing for a paucity of application:

"'we always ask miss questions like, 'why are we learning this?' and she doesn't really seem to give an answer… I can't think of anything where we'd use algebra for…"(borderline student)

The second goal of mathematics education covered by the follow-up questions was preparing learners to use mathematics in the workplace. As with the first goal, most participants considered this a valid and genuine purpose of learning mathematics, although some qualified this agreement and others offered examples which could be criticised as being cursory. Hence whilst one male lower grades learner held that "whatever job I think there's maths involved in it", others including one male borderline learner were less definite: "maybe if you're an accountant… or in finance, but… if you've got a calculator you should be alright." A second male borderline learner held that mathematics was not pertinent for "outside jobs". Jobs involving finance or money were the most frequently cited examples; for instance one borderline female learner mentioned banks and supermarkets: "the only thing I can think of is money, or like working out a percentage of something". Other occupations raised included carpenter, builder, teacher, scientist and police officer; conversely, one borderline female learner could not provide a single example, even when pressed.

At this stage a salient question is whether the students' appreciation of the two goals discussed above, and their capacities to discuss these goals, can be associated with either how they had been ability grouped in mathematics or their school. Whilst the size of the interviewed sample prohibits conclusive or proportional analysis, the qualitative data does appear to belie robust associations; strong and weak responses were presented by students in both groups of learners, and a spread of sophistication was present in the responses from each school. The students' ATMI scores also failed to correspond conclusively with their ability to offer concrete examples, suggesting that learners' reported appreciation of mathematics did not rely solely on being able to identify specific uses. For example, whilst one male borderline pupil (ATMI score 162) could offer a number of ways in which mathematics might be useful in daily life and in employment, a female borderline learner from the same school (ATMI score 184) said of mathematics "I think it's a good lesson to learn, I think it helps you with like a lot of jobs and stuff… probably most of them… but I don't know what." However, there was a suggestive correspondence between gender and the learner's response; the male students' answers to these questions typically involved a greater appreciation of the utility of mathematics, observing a wider range of potential applications and concretising more readily. Further to this, real-life experience seemed to be potent in supporting some students' responses, with a small number relating anecdotes of how mathematics had been used whilst out with parents, in part-time employment, during work experience on a cattle farm and within a vocational BTEC course; these students also all reported relatively high ATMI scores.

The role of GCSE mathematics as a gatekeeper qualification was almost universally acknowledged by the students interviewed. Some students discussed specifically how they needed to do well in mathematics to be accepted by a college, or into a particular career, whilst others talked more generally about needing to pass GCSE mathematics to get a “good job” or a “better job”, with especial attention being awarded to the key C grade. There was evidence that the discourse of mathematics as gatekeeper was both widespread and deliberately propagated by some teachers, for instance, one borderline male student offered that "you get told what people look at most in jobs… if you get a low grade, then you're not going to get the job…" In another particularly blunt case, a male borderline student described GCSE mathematics as a “very needed qualification”, then explained that his teacher “just says it straight”: “She says if you don’t get this C grade, you’re not going to do very well in life.” However, whilst these students appeared to have inherited some form of this discourse, they did not all fully understand it; a female borderline student from the same school as the previous quoted student recognised that she needed a C for her chosen career and assumed that mathematics must be useful, but she was not sure why: “I think we’ve just been told… I’ve heard a lot of people saying that you need to learn maths…”

Some students did go on to consider and suggest reasons why mathematics had been established as a gatekeeper subject. A few were able to suggest specific ways in which learning mathematics might help in their chosen jobs: one borderline student who wanted to work in retail saw the gatekeeper role working in tandem with her developing skills with fractions and percentages, whilst a lower grades student who wanted to become an engineer could offer hypothetical situations where mathematics could be useful, such as measuring out detonating cord. Conversely, others saw the accomplishment of a C grade as evidence of a more general competence or aptitude. One borderline student questioned whether it acted as "evidence that someone has made an effort and that they are a hard worker?” Another borderline student suggested that a C grade showed that “you didn’t mess about and stuff”. Predictably the place of mathematics as a gatekeeper seemed to generate more concern amongst some, although not all, of the students working towards lower grades. One male learner offered that sitting the exam in mathematics was particularly scary because “the whole life is in front of you”. Another male lower grades learner seemed strikingly concerned by how a low grade might limit his opportunities:

"if I can't scrape a C grade, then I can't go to university… anything under a C is rather, it's not acceptable really… other people my peers are going to kind of progress, and I'm going to be left behind… I kind of aspire to do things and I think that maths really is kind of like the elephant in the room.”

A small number of students brought up others of the goals and roles of mathematics education identified in chapter one of this thesis. One borderline male student appeared to recognise that learning mathematics could help develop more general logical thinking; in his questionnaire he argued that “maths is not the easiest subject to learn so enhancing the skill to learn maths would enhance the way we learn new things in the future.” A second male borderline student had written in his questionnaire that everyone has to learn mathematics to “make the school look more impressive and give it a good reputation”; he expanded on this point in the interview, making it clearer that he had inferred this position from hearing discussions about school league tables and how other subjects were requisite for contemporary government performance measures such as the English Baccalaureate. Finally, one lower grades male student offered that an individual’s qualifications in mathematics could be taken as an indicator of their overall intelligence:

"...say if you compared people that did French I think a lot of people would say if they did struggle with French and, they'd say, 'oh, it doesn't matter it's only French' yet, if you went on to do maths and you struggled with maths and they'd say well, 'you know, you really need this, it's a key thing to your learning and if you can't do it you're not as clever as the next person.'"

5.4.2 Philosophy, Purpose and Performance – One Student's Story

It is beyond the scope of these interviews to conclusively demonstrate or describe the relationships between each learner's beliefs and actions with regard to learning mathematics. Nevertheless, there were indications in the data that each learner's philosophy was in some cases meaningfully related to both their experience and their attitude. The most extreme case was arguably a female borderline student with an ATMI score of 86, who will be considered here in some detail. This student questioned the utility of the mathematics she was learning and, in consonance with many of her peers, had drawn a distinction between useful and less useful mathematics:

"I just don't like the way it's compulsory, like I think to a certain stage it should be but I think, the stuff that comes up in tests now is pointless, really... the only thing I would say that I use is just adding and subtracting and I do that in my head. Or timesing and dividing, just the basics that you learn at primary school, really."

She related that she had been exposed to the gatekeeper discourse, having recently attended "a presentation just saying, 'it's helpful and blah blah to help you do so and so'." Yet her paucity of experience with the applications of mathematics, together with some observations she had made of how mathematics was presented by her parents and in the media, ostensibly led her to decry the claim that GCSE mathematics was intrinsically valuable:

"…I think it's all about what looks good on your C.V., I don't think it's necessarily that you're going to use it…"

She even went as far as to consider the rationale behind the current system, offering the following comment which hinted at cultural reproduction:

"…'cause everyone learns it then it's something that you kind of, like it's expected of you but if… it was made compulsory and not everyone chose it… I think 'cause it's in the mindset of people at the moment that you need to know maths because everyone knows it but if… not everyone did all the harder stuff at maths then it wouldn't be so…"

This borderline student openly recognised that her views on the purposes of mathematics education were affecting her performance:

"I think I've got the ability to do OK in maths I just… don't make, put much effort in, because of my views of it."

Whilst the interactions between philosophy and performance in the mathematics classroom are undeniably complex, multifaceted and even subconscious, this acute case is offered here as a vignette of how one GCSE learner had, at the point of interview, recognised and considered some of the co-existing goals and roles of mathematics education and made sense of their own mathematical purpose.

Unfortunately here, this process had resulted in the student developing a largely negative view of mathematics and adopting an attitude of reasoned disaffection.

5.4.3 Experiencing GCSE Mathematics

The remaining interview questions focused on each student's experiences of GCSE mathematics, exploring how practical and pedagogic aspects of school mathematics learning might contribute to the processes by which students positioned themselves with respect to mathematics. Although the accounts generated continued to be highly personal and individual, they did return some common themes and shared experiences which are summarised below.

Three students described their experiences of ability grouping in some depth; notably all three were working towards lower grades at GCSE mathematics. Whilst one felt that the "grading system that we have, where we have different classes different abilities, isn't bad…" the other two disagreed, citing ability grouping as something that hindered their learning. The first drew a comparison between learning in mathematics and English:

"…because you're in sets, I know they do it different in English, like mixed ability… for me I think if you're with mixed ability, it'd be better, 'cause you've got people in top sets, and if you don't understand some of the stuff, like the basic stuff and those guys do, instead of the teacher helping you all the time you've got them…"

The second offered that learning in the bottom set was repetitive and lacked challenge:

"…I've always been put in the bottom set for maths, 'cause it's not my strongest, but… I just always get it right, and it got boring… I got it right and it got boring getting it right every time getting it right 'cause I… don't really think I really learnt from any mistakes. 'Cause we got the same work set pretty much every day."

Some of the borderline students did discuss their tier of entry within their interviews, but only briefly; typically each mention focused on strategic plans, such as first securing a C grade on the foundation paper then moving onto the higher paper. It is possible though that the location of multiple attempts at examinations in the students' personal futures limited their concerns about tiering and that this is a weakness of the methodology, consequent from researching learners in Year 10.

Negative comments about activities and pedagogic approaches, typically bemoaning book work or extended periods of listening to the teacher, were present and much more common amongst lower grades students, with one complaining that "it seems like the lessons go on for ages." Corresponding positive comments included remarks about games and interactive elements. The pupils from school C, the school which had reported the highest typical ATMI scores, offered a number of positive comments in this area: for example, one appreciated the opportunities given to go over old examination papers and identify areas for improvement; a second liked the feeling that at the end of a lesson he knew something which he had not known at the start; and a third enjoyed working in small groups on mathematical tasks. Another particularly positive remark came from a student at school D who appreciated how his teacher used purpose to inform pedagogy:

"…my teacher sort of explains stuff if I don't understand it quite well… (he) does sort of more interactive stuff… 'cause maths is one of those subject that people tend to hear the word 'maths' and it's just 'aargh', hate it… but I think it's good how you can… involve day to day stuff and scenarios."

Whereas literature such as Nardi and Steward (2003) argues that the repetitive and depersonalised practices described by some of the students above have poor attitudinal consequences, this last quote offers a counterpoint: that engaging and considered pedagogy can be employed to support learners in developing a positive mathematical identity, even when these learners are exposed to and aware of other, negative discourses.

The teacher was an important figure in many of the constructed narratives, both as an individual and in establishing the tone for the wider classroom culture of learning. For many students the relationship with the teacher was critical:

*"Well, I moved back into Miss ***'s class… and I found it better in that classroom… my grade has gone up, compared to the class I was in before… I think the way she teaches makes me, take it in more and learn."* (borderline student)

"…she's a really good teacher… I get on with everyone, but… there's just some teachers I work with, and some teachers just don't… but I try as best as I can to get on with everyone…" (borderline student)

"I don't really like it 'cause… the teacher's a nag… tries to make… himself more like a student than teacher, sort of thing." (lower grades student)

One important feature of the culture of the mathematics classroom appeared to be the way in which questioning was handled, such that restrictions on a student's ability to question impacted on their positioning within the community of practice. This seemed to be more of a present concern amongst students aiming for one of the lower grades in GCSE mathematics; for instance:

"…my teacher doesn't like me, and I don't like him, 'cause he's always shouting at me… when my teacher explains something and I don't understand it and ask for help, he assumes I weren't listening, when I was…"(lower grades student)

Compounding pressures had also been inferred from other learners' attitudes toward questioning; another lower grades student said she "felt embarrassed if I asked for help" in mathematics lessons, "'cause everyone knows what to do and I don't understand it." Despite such pressures most, but not all, of the students who discussed group work tasks said that they enjoyed working with others in mathematics lessons.

Competition was a present but not prevalent feature of the interview data. The narratives of two contrasting students illustrate how competition can contribute to students' developing mathematical identities. When asked about what grade he thought he was going to get at GCSE, a lower grade learner with a very low ATMI of 66 bemoaned that "in every maths test I've gotten… the lowest result… I still reckon I'm going to get the lowest." Conversely, when asked about his favourite topics in mathematics, a borderline learner with a very high ATMI of 162 chose "expanding brackets and… factors and stuff like that… I just know how to do it, and, I zoom through it straight away and then just feel good when I've done it, and everyone else is like, 'ah, how do you do this?' I feel like I got something that other people haven't." As well as suggesting that some GCSE students position themselves with respect to mathematics by considering their relative positions in a perceived classroom hierarchy, these quotes are redolent of the reflections offered with hindsight by some of the adult and undergraduate learners respectively.

In addition to the impact of the teacher and pedagogy on enjoyment, attainment and enjoyment were allied in the majority of the interviews. Each factor was reasoned to influence the other; for example, one borderline pupil suggested "I think I'd like it more if I found it easier" whilst a second offered that "if I find something enjoyable I usually do it good." This dual association often featured within the structure and shape of the students' mathematical trajectories. One negative example was offered by a lower grades student who had enjoyed learning mathematics until Year 4 in primary school, when "it just got like really stressful and like really really hard… really really boring and I thought the lessons dragged on for ages." A positive counterpoint was offered by a borderline student who had not enjoyed mathematics lessons at primary school, but having attended some support sessions out of school enjoyed it more at school: "…'cause… when I got back to school, I knew more what I was doing, and I was kind of ahead of the game…"

Most of the interviewed students seemed to consider that they had some agency over their performance in the mathematics exam, with many appearing to have thought about how they might revise or prepare more effectively; only a few adopted a resigned tenor when discussing the GCSE. The majority also appeared to have realistic expectations, largely in line with the information provided by the centres. Memorisation was a significant concern for some learners though, notably amongst those who exhibited lower levels of agency. For instance, one lower grades learner who protested “I’m just going to get an F” offered that:

"you've got a massive exam… you've got to remember everything… when I like sit down like one table at a time…it just goes and like, I don't know anything!"

Procedural recall appeared to be similarly of concern amongst borderline students; for instance one complained that "there's a lot of stuff to remember, like how to add certain equations and, fractions and stuff." In light of these anxieties, it is unsurprising that many students undertaking a modular GCSE course praised the reduced load on their memory: "I probably get better result from only having to remember little bits at a time…"; “…I wouldn't be able to remember anything if I did it like in one massive test at the end.” Only two interviewees offered contrasting views, suggesting that one terminal exam would give students more time to revise and reduce clashes with coursework deadlines from other subjects.

To close this section, it is of note that the interviewed students from school C offered comments which broadly supported the line of argument laid out in section 5.3.4.3, that is that an early, low pressure first entry for students in Year 9 might better familiarise learners with the practice and content of GCSE mathematics, and assuage some attendant concerns and anxieties. One borderline student from this school thought that they had already achieved a C grade and, whilst they thought themselves unlikely to improve on this, was looking forward to retaking the GCSE because they enjoyed doing mathematics. The other borderline student from this school had achieved a D grade in their first attempt and felt “pretty disappointed”. However, this had motivated them to do better, and they were currently working at a C grade. They intended to “do foundation for this year, to make sure I get my C” and then move onto some modules from the higher tier in Year 11. The first lower grades student could not recall the result of their performance in Year 9 but seemed to have realistic expectations of aiming for a D grade as a final outcome. They also agreed that they felt more confident after being entered more than once, as if “…you don’t get the grade that you want, you can always revise more and, get your head down… try for a better grade.” The second lower grades student partially concurred; they had attained an F grade in their first attempt and felt better about sitting the GCSE, although they were “still nervous.” Whilst the brief comments of four students do not speak conclusively to such a significant matter, they do offer some convergent support to the earlier reading of the quantitative data.

5.4.4 Agreement and Convergent Validity

The interview data corroborated the findings of the questionnaire data in many respects, supporting the validity of this component of the research. Mathematics was again acknowledged as important, with students recognising that it has utility in both everyday situations and workplace contexts. The concern suggested in section 5.3.1 by ATMI item 8, specifically that some pupils nevertheless had problems identifying mathematics in their own lives, was confirmed the interview data. The role of mathematics as a gatekeeper subject also continued to be acknowledged. The interview data went on to explore some of the issues raised by the quantitative data in more detail. For instance, the interview narratives introduced some issues regarding the pedagogy of the mathematics classroom and returned to the importance of questioning, originally considered by item 38 of the ATMI.

Although it is proper to note that the size of the interview sample constrains any appeal to convergence with regard to differences between genders, cohorts or schools, all of the noted trends involving these factors were in line with the wider quantitative data. For instance, the greater apparent readiness of male students to identify applications of mathematics, noted in section 5.4.1, fits with the higher ATMI scores reported by males in section 5.3.3. Further, the comments of the students from School C in section 5.4.3 resonate with the discussions of this centre's ATMI results as presented in sections 5.3.4 and 5.3.4.3.

In these ways and others it can be argued that the data gathered through the use of the two instruments forms a meaningful and coherent whole, which addresses the local research questions and can now be used to speak to the global research questions.

5.5 Discussion

The results and accompanying comments above have spoken to the three local research questions, by exploring the learners' views of mathematics, their own studies and how the learners had positioned themselves with respect to mathematics. This section will briefly consider how the data reported in this chapter might also further inform the two global research questions in advance of the synoptic discussion contained in the next chapter.

5.5.1 Discussion of the Global Research Questions

The global research questions were stated in section 1.3 as follows:

- How do the experiences and mathematical trajectories of learners reflect the competing goals and roles of mathematics education?
- How do learners navigate and make sense of competing or co-existing goals and roles of mathematics education? In particular, how do they make sense of their own mathematical purpose?

Although the statutory structures of secondary education limit comment on how the trajectories of these learners to date reflect the competing purposes of mathematics education, the data above has exposed ways in which the goals and roles identified in chapter one are present in the experiences of borderline and lower grades students studying towards their GCSE in mathematics. It also speaks to how some of these learners might navigate or make sense of these goals and roles, and how these processes might in turn inform their developing mathematical identities.

Both the questionnaire and the interview data demonstrate that the GCSE students included in the study predominantly recognised the purposes of mathematics education as: equipping students with an everyday numeracy; preparing students for the workplace; and leading towards a qualification which acts as a gatekeeper within further education and employment. However, the data also makes it clear that whilst almost all of the students were familiar with the discourses attached to these three intentions, not all students were able to explain or expand upon these discourses beyond general statements of purpose; this variability in turn can be held to be indicative of the ways in which schools, teachers and students had navigated the multiple purposes of mathematics education, as well as being reflective of the students' resulting mathematical identities.

In this way, whilst the accounts related in this chapter largely involve the same goals and roles of mathematics, different experiences arising out of specific schools, teachers and pedagogic approaches can be reasoned to contribute to the making of layered discourses. These in turn can support the student in either aligning the purposes of mathematics education in co-operation, or arranging them in competition. In extremis, a student who is encouraged toward developing a fuller facility which can recognise mathematics in a greater variety of contexts is more likely to see mathematics as both practically useful and personally valuable and so inculcate a positive view of mathematics. Conversely, a student who is rarely encouraged to apply their mathematical learning but is often reminded of the cultural capital of the GCSE qualification, or one who is exposed in another way to an imbalanced presentation of the discourses attendant to the purposes of mathematics education, is forced to rationalise an apparent conflict and risks the development of a negative view of mathematics. The narratives constructed in the interviews recurrently exhibit some of these rationalisations: sections 5.3.5 and 5.4.1 gave examples where mathematics was partitioned into 'useful' and 'not useful' components; section 5.4.1 discussed the strategy of deferral, wherein mathematics would be useful 'in the future'; and the same section reported occasions where the roles of mathematics subsumed the goals, such that mathematics was reasoned to be principally a marker of general intelligence, aptitude or effort. As recognised in section 5.3.1, though each learner's mathematical identity and identity-making processes are unique and multi-faceted, the data can be understood as evidence that casting mathematics as valuable but pointlessly difficult, or valuable but desperately abstract, can force rationalisations which contribute to the development of identities of marginal participation and strategic compliance, or even disaffection and withdrawal as suggested by the vignette of section 5.4.2.

The following extract from a lower grades student's interview is offered as one final example of how a perceived imbalance between the goals and roles of mathematics education can lead to the construction of an identity of deliberately limited marginal participation in a GCSE student. It is notable that this student reported an ATMI score of 120, which is a theoretically 'neutral' score (see section 5.3.1). However, this summary statistic disguises a more difficult picture of the practical and social values of mathematics:

"I probably do think that maths is more important for getting a job than it is as a practical skill for the world… I think if you didn't say have a GCSE in maths I think you could get by doing everyday things – you could go shopping, you could go places and do things and still earn money and do a job and all this… I do believe it's seen as a kind of competence thing."

Later on in the interview, this student demonstrated clearly that his views of the place and purpose of mathematics education had already steered his trajectory before leaving school:

"I suppose it's an important skill and, with the way that our society kind of rolls, everything is based on numbers. It's just in my life, I've kind of made sure it's not."

A critical reading of the purported situation is that rationalisation strategies such as those discussed above are in the main adverse on the part of the individual; by having negative affective profiles at their centre they both impact upon the individual's wider academic self-image and limit their adopters' access to the potential power of mathematical thinking and learning. Perhaps ironically, the overstressing of mathematics as a gatekeeper subject thus risks dissuading many learners on or below the borderline of a C grade away from not just the qualification and the opportunities it entails, but also from a powerful and purposeful skill set and way of thinking. A critical reading ought to note further that the quantitative data above submits that this risk is more profound amongst learners in 'bottom sets' and female students. More progressively, the data can also be understood as invoking a germinal list of factors which might either contribute or check the adoption of these strategies; the accounts of section 5.4.3 extend how teachers, pedagogic approaches, classroom questioning, ability grouping and the use of different examination structures can all shape students' mathematical identities. The recognition of other, more infrequently cited goals and roles of mathematics education might also impact upon this process; for instance, an appreciation of the goal of mathematics education as the development of a set of thinking skills might help incentivise learning more fully in instances where the mathematical content seems more abstract.

In conclusion, the data in this chapter can be understood as supporting the argument that the processes by which learners make sense of apparent competition or co-operation between the goals and roles of mathematics education can be decisive in building the learners' mathematical identities and informing their personal senses of mathematical purpose; in agreement with Solomon (2007b), it is not only learners' experiences which contribute to their mathematical identities, but also the ways in which they interpret, evaluate and make sense of their experiences. Although some of the quotes presented here might be explicated more straightforwardly, for instance by proposing that the narratives comprise post hoc defences of perceived failures, it is maintained that the argument presented above is both more constructive and more coherent, and that it fits the included narratives more closely. It also serves to explicate observed differences in the quantitative data between ability groups and gender by admitting the relevance of stereotype threat, as well as illuminating why schools with distinct examination entry protocols might present such different affective profiles. Further, this line of reasoning includes and expands upon features which are present in the previous sets of data presented in this thesis. These similarities and developments will be considered below in chapter six.

CHAPTER SIX: NAVIGATING MATHEMATICS

6.0 Introduction

The groups of learners researched in the preceding chapters have been significantly dissimilar, being taught different levels of mathematics at different ages and in different institutions. Nevertheless the shared features and correspondences in the presented narratives suggest how the multiple purposes of mathematics education in contemporary England can influence learners' mathematical trajectories and mathematical identities.

Whilst working both as a teacher and within teacher education, I have heard it anecdotally cited that the bane of many mathematics teachers' practice is to have pupils ask at inconvenient moments "why are we doing this?" Whilst this question is undoubtedly deployed on occasion by students as both idle inquiry and a delaying tactic, it might also be taken as a signal of something far more profound. This chapter will set out that the fundamental yet often neglected notion of purpose, taken to include both the goals and roles of mathematics education, can be used to inform understandings of mathematical trajectories, mathematical identities, the potential impacts of different pedagogies and other aspects of the wider affective domain. It will also argue that a deeper consideration of the purposes of mathematics education has the potential to serve as an emancipatory tool with which teachers, policy makers and politicians might critically examine their own practice.

6.1 The Influence of Goals and Roles on Trajectories

The first global research question was originally presented in section 1.3: how do the experiences and mathematical trajectories of learners reflect the competing goals and roles of mathematics education? The term 'goals' was used to refer to intentions which were typically explicit and related to the intrinsic worth of mathematics, such as:

- Ensuring numeracy at the level of the individual;
- Preparing learners for employment and further education;
- Promoting interest in the use and study of mathematics;
- Cultivating thinking and problem-solving skills; and
- Developing a critical citizenship.

The term 'roles' was concurrently used to refer to purposes of mathematics education which were primarily implicit and connected to the place of mathematics in society, including:

- Aiding in processes of social and cultural reproduction by forming the basis for a gatekeeper qualification and otherwise;
- Serving as a monitor of performance in education; and
- Acting as a shorthand marker of a learner's general intelligence.

It is impossible to answer the first global research question wholly; each learner represented in this thesis has an individual mathematical biography and has been motivated by a unique interpretation of the purposes of mathematics education. Nonetheless, it is possible to note trends in these biographies and consider them from a critical theory perspective. Chief amongst these trends was found to be the influence of mathematics as cultural capital (Bourdieu 1973).

The gatekeeper nature of mathematics and its attendant qualifications is pre-eminent in, and pervades throughout, each of the preceding data chapters. The prospect of advancement in future education or employment was vital in many of the accounts constructed by both adults returning to mathematics and students at school; correspondences between the quotes offered by these two groups are manifest. For instance, whilst mathematics was described by one borderline school learner as “a qualification that everyone needs, or… you’re just not going to get a good job, are you?” an adult learner opined that “if I’m going to get any sort of job in the future, my maths has to improve…” Equally, just as one lower grades school learner held that “if I can’t scrape a C grade, then I can’t go to university”, an adult numeracy learner admitted that she had “realised that most universities require at least a pass in maths before you can be admitted to do any course.” These written responses are not atypical; the quantitative data sets examining the motives behind the return to mathematics in section 3.4.5 and the value attached to mathematics in section 5.3.1 further support that the recognition of mathematics as something which is of considerable value in contemporary society is pervasive. In a similar manner, the worth of a mathematics degree was shown to be influential in steering the mathematical trajectories of the undergraduates, for example in Adam’s admission that “it was more I think of a career motivation than anything else” or in Cathy’s comment that “getting a maths degree will probably take you quite a lot of places… you can pretty much do anything you want if you've got a maths degree." The experiences and mathematical trajectories of many learners thus stem from a desire or need to procure a mathematical qualification.

The prominent influence of the GCSE qualification has also been illustrated through comparisons between subgroups of learners. The data presented in chapter 3 highlights multiple differences between the trajectories and attitudes of adult numeracy learners and those working towards the GCSE examination; similarly the data of chapter 5 presented statistically significant evidence (for instance in section 5.3.2) that borderline students, who are more likely to attain a C grade than lower grade students, typically have correspondingly higher affective profiles and enjoy mathematics more. In consonance with research summarised in the previous chapters (for instance Solomon 2007b; Boaler 1997; also Hallam and Ireson 2005), many learners appear to have qualitatively different experiences of learning and coming to know mathematics, guided by ability grouping and their proximity to established standards of qualification.

The attention afforded to mathematics appears to be not only consequent of the potency of any particular qualification however, but also something which exposes the place of mathematics as cultural capital in a fuller Bourdieusian sense; although the research instruments were not attuned explicitly to look for evidence of processes involving social or cultural reproduction, the data nonetheless held some salient trends and discursive markers. That many of the adult learners wanted to be able to help their children with mathematics, so as to boost their cultural funds, was discussed in chapter three. However, it is perhaps more telling that this motive for studying mathematics was also given by one of the lower grades GCSE learners: “so that you can teach the kids what you’ve learnt…” The vignette presented in section 5.4.2 also hinted at an emerging recognition of reproduction in mathematics education: “…’cause everyone learns it then it’s something that you kind of, like it’s expected of you but… I think ’cause it’s in the mindset of people at the moment that you need to know maths because everyone knows it…”

The mathematical trajectories and experiences of learners thus take great account of the role of mathematics qualifications as gatekeepers and cultural capital. However, the presented data demonstrates that this function rarely if ever shapes the experience of mathematics education in isolation, rather that each learner is steered by and exposed to a context-dependent blend of goals and roles which informs their resultant trajectory.

As noted in section 4.6, the typical trajectories of the adult learners returning to the formal study of mathematics and those of the undergraduates leaving mathematics behind suggest a certain symmetry. Whilst many of the adult learners had opted into the formal study of mathematics in search of cultural capital, their return to mathematics led them to a more general appreciation of the goals of mathematics, most notably those of establishing an everyday numeracy and preparing learners to use mathematical skills in the workplace; in this way the goals and roles of mathematics education were considered to have moved more into alignment. Contrariwise, the university experiences of the undergraduates involved a shift within the balance of the underlying goals, with the immediate application of mathematics becoming secondary to the inculcation of more abstract logical thinking. The failure of the undergraduates to reposition themselves in light of this new formulation of legitimate mathematical practice led to a decoupling of the goals and roles of mathematics education, such that the mathematics degree was still valuable but less valued. In addition to these two findings, the GCSE students presented a range of nascent positions with respect to mathematics, within which the goals and roles were variously arranged in alignment and opposition.

A critical overview of these summaries might therefore contend that learners who more fully subscribe to both the goals and roles of mathematics have higher affective profiles, and vice versa. Yet whilst this holds true for some individuals, it is not the case for all of the individuals represented in this research. For instance, the discussion of section 5.4.1 illustrated that within the GCSE student sample, a high ATMI score alone was not a guarantee of an extensive appreciation of how mathematics could be used in the workplace. Instead the data speaks to the authority of learners' discursive accounts of their own experiences (Solomon 2007b); it can better be interpreted as demonstrating that it is not the learners' personal understandings of the purposes of mathematics education which impact upon their trajectories, but rather their psychological responses to these internal impressions.

This reading thus speaks to present debates (such as those within Vorderman et al. 2011) about retention and participation in mathematics education by dually foregrounding learners' perceptions of both the worth and purpose of mathematics as a discipline and also of themselves as legitimate users of mathematics. It also speaks back to the first global research question and interrogates its use of the word 'competing'. The notion of competing goals and roles within mathematics education is perhaps fair in the sense that they might compete for priority in policy, or within learners' minds, but in an absolute sense none of the goals or roles outlined in chapter one are philosophically contradictory; conflict or incompatibility is instead inferred from mediating experiences. What the data reveals about these experiences, and about the channels through which meaning is communicated, will now be considered further in discussing the second global research question.

6.2 Coming to Know the Purposes of Mathematics Education

The second global research question was articulated as follows: how do learners navigate and make sense of competing or co-existing goals and roles of mathematics education? In particular, how do they make sense of their own mathematical purpose? In light of the preceding data, this question can be considered to conflate two lines of enquiry. First, in what forms, and through what channels do the discourses involving various purposes of mathematics education come to reach individual learners? Second, how do individual learners make sense of and react to these exposures, so as to make sense of their own mathematical purpose? These two lines of enquiry will be considered in turn, in this section and the next.

Taken holistically, the data illustrates that discourses about the purposes of mathematics education are delivered both explicitly and implicitly. On occasion the narratives relate instances that name a specific discourse; for instance, one borderline student related that "you get told what people look at most in jobs…" Yet much of the philosophy which contributes to learners' mathematical identities appears to be inferred from aspects of the organisation and practices involved in teaching and learning mathematics. For instance, the narratives demonstrate quite clearly how curriculum content and design influences learners' perceptions of mathematics.

The most dramatic comments concerning curricula were offered by learners who had recently experienced contrasting programmes of study. The undergraduates had moved from a curriculum based around the application of mathematical methods to one centred on mathematical proof. This led John to lament that "we're suddenly doing something which isn't – it isn't maths that I knew, that I enjoyed and that I was good at." This quote clearly demonstrates that the shift in curriculum had changed how John viewed the nature of mathematics. Equally, the adults who had found themselves on courses "designed around real life" had found themselves encouraged to perceive mathematics as something which had relevance to their daily lives. The bias inherent in this curricular model had thus impacted on adult learner E's view of mathematics and its relationship to 'real life': "Especially when I was doing the course, I was constantly thinking of things in the world, and sort of adding things, and trying to fit them into things that we had learnt in the class." Further, whilst the GCSE students were all undertaking fairly similar prescribed curricula in mathematics lessons, students who discussed enlarged programmes of mathematical study involving work experience or vocational study seemed to demonstrate a greater capacity to connect their mathematical learning to real-life. This suggests again how learners' views of mathematics, and hence their views of the purposes of learning mathematics, are influenced in the first instance by what they have been taught and the tasks which they have been exposed to (Henningsen and Stein 1997; Hiebert et al. 1997).

The data goes on to confirm that messages about mathematics are also embedded in the manners of teaching and learning (for example Bibby 2009); all three groups of learners commented on pedagogy in the mathematics classroom. The adult learners' remarks about explanations which include context again suggest the presence of inherent backing of the idea that those who learn mathematics develop a skill which is personally useful, as does the lower grades GCSE learner who remarked that "I think it's good how you can… involve day to day stuff and like scenarios". Yet it is the changes within the narratives of the undergraduates that most dramatically illustrate connections between philosophy and pedagogy. As noted in section 4.5.1, by default or design certain goals of mathematics education appear to have become allied with particular pedagogical techniques: for example, the 'ten questions' model of classroom activity supports a discipline intended to develop quick, efficient technical facility whilst extended exercises involving higher-level thinking skills, particularly when based around the construction of proofs, fit more closely with the goal of sustaining mathematics as an intellectual field of human enquiry. Pedagogy thus serves as a second basis from which learners can make inferences about the purposes of learning mathematics.

A particularly salient element of pedagogy raised by all three groups of learners was the place and use of talk within mathematics learning. Styles and uses of questioning, when integrated consistently into a community of practice, not only invite learners to position themselves with respect to the learning process, but also allow them to infer something about the purpose of the learning itself. When questioning by the learner is invited readily and openly, the implication is that the learner is at the centre of a communal learning process, where the approach and the content both hold purpose for the individual (Alexander 2008). This was the case for many of the adult learners as described in section 3.4.6.1, for instance: “My current maths tutor is fantastic, if you don’t understand she will explain it in as many different ways as possible until you do. She also relates all our maths to everyday life.” Conversely, whenever questioning within learning is limited or openly discouraged, the implication can be that the learner is primarily required to keep up or ‘prove themselves’ using their own intellectual capability, suggesting that each mathematical concept is more akin to an intellectual standard which must be met, rather than mastered. This perception was shared by the undergraduates leaving mathematics behind, such as Cathy, who felt unable to ask questions in lectures and regretted asking questions of her tutor in private: “Like, they’ll say things like so obviously this follows, and this is obvious, this is trivial, and you’re like ok, this just makes us feel stupid because anything that they say is trivial that I don’t understand, I then feel completely stupid.” The questioning and subsequent explanation styles described by many of the adult learners supported them in recognising the purposes of developing a personal numeracy and preparing them for the workplace, whereas the frustrated questioning outlined by the undergraduates more closely supported the recognition of the role of mathematics as an intellectual marker, and the goal of perpetuating and extending mathematics as a field of intellectual enquiry.

The figure of the teacher or lecturer also featured as a strong influence within many of the narratives across all three groups, with many of the adult education learners commenting on newly forged positive relationships, and the undergraduates noting the loss of an accessible figure. Differences between teachers were held by some of the GCSE students, such as this borderline student, to impact on both affect and performance: “Well, I moved back into Miss ***’s class… and I found it better in that classroom… my grade has gone up, compared to the class I was in before… I think the way she teaches makes me, take it in more and learn.” In light of this significance, it is arguable that it is not only pedagogy which mediates purpose, but also personality. Individual teachers steer their students’ perceptions of mathematics education by reflecting their own beliefs through their practice (Ernest 1989) as well as by serving as models of what it means to be a user of mathematics; the students' inferences contribute in turn to their own understandings of the purposes of mathematics education.

Finally, the data also institutes that learners can infer purpose from the ways in which mathematics teaching and learning is organised, for instance through ability grouping. The comments offered by the adults in section 3.5.5 illustrate that being in any set can impact negatively upon affect and establish mathematics as a competitive activity; this practice also encourages learners to recognise the role of mathematics as a marker of general intelligence. Ability grouping can further steer the previously cited mediators of curriculum and pedagogy, perhaps explaining why one lower grades GCSE learner bemoaned having “the same work set pretty much every day.” The management and presentation of mathematics examinations can also stress or limit the presence of different discourses regarding mathematics education, as argued in section 5.3.4.3 amongst others.

In summary, the discourses surrounding the purpose of mathematics education are communicated to individual learners through a number of channels, notably including: the curriculum they follow; the pedagogy they are exposed to; the individual teacher or teachers they work with; and the ways in which their learning is managed and organised. Any philosophy of mathematics education, including its purposes, is thus disguised in, transmitted through and inferred from what might be termed the wider grammar of learning mathematics. This grammar reflects layered discourses which operate on a number of levels; learners are influenced by features which function at a national level and at a school level, as well by individual experiences that happen within their own classrooms.

6.3 Navigating Layered Discourses

The discussion above has illustrated some of the ways in which learners are exposed to layered discourses regarding the purposes of mathematics education. Upon exposure, each learner is faced with the task of constructing a coherent mathematical identity which not only responds to these discourses but also recognises their own experiences and actions, and makes sense of their personal mathematical purpose.

It is inexorable that any personal construal of mathematics education must be in part reflexive, incorporating both the inferred structure of mathematics as a discipline and the agency of the individual learner. In this way, the formation and reformation of mathematical identities must involve conceptualisations of both mathematics as a discipline and the individual as an employer of mathematics, with each position contributing to and informing the other (Black, Mendick and Solomon 2009; Holland et al. 1998). The accounts presented in this thesis have already illuminated a wide range of ways in which learners have conducted this reflexive process, navigating and making sense of the various discourses surrounding mathematics education. The preceding analyses of resonances and trends in each set of data together suggest that these methods typically centre around learners' perspectives on value and achievement.

The data consistently holds that mathematics is afforded value by the vast majority of learners. With only occasional exceptions, the quantitative data sets in particular suggest that all learners in the studied contexts recognise mathematics as a valuable field of study in some sense; indeed, this is perhaps inexorable given the cultural circumstance and contemporary staging of mathematics education in England as described in chapter one. The process of making sense of discourses about purpose is therefore primarily dependent upon placement within a spectrum of achievement.

Towards one end of this spectrum are learners who see mathematics as valuable and themselves as competent users of mathematics; this class would contain the described undergraduates in the early parts of their narratives. For these learners a positive view of mathematics mutually reinforces a positive view of themselves as users of mathematics; at the end of the spectrum an accumulative advantage could be postulated, encouraging both continued participation and the espousal of mathematics as an esteemed, even a superior pursuit. Whilst this can ultimately result in cycles of attainment and positive academic self-images, the narratives of the undergraduates in chapter four have illustrated how this feedback can form the basis for incautious identity building which may be ultimately harmful when the nature of mathematical practice or success is redefined.

At the other end of the posited spectrum are learners who see mathematics as valuable yet recognise that they are failing to achieve an expected or assumed standard. In these cases each learner can either accept this shortfall and adopt a negative self-image, or attempt to assuage or rationalise this conflict; this class would certainly contain many of the GCSE students and the undergraduates in the later parts of their narratives. The qualitative data contains few instances which are suggestive of acquiescence but many which draw on ego defence strategies recognised in the psychological literature (Paulhus, Fridhandler and Hayes 1997; Tesser 2000). For instance, Mark and Cathy's favourable comparison of their degree course against those of other universities can be read as an instance of social comparison. A number of observed defences could be described as minimisation strategies, combining denial and rationalisation. These occur frequently across the data, particularly but not exclusively amongst the borderline and lower grades GCSE students.

The resonances between the data sets suggest that there are at least three recognisable trends in the ways that learners attempt to protect themselves psychologically from failure in mathematics through minimisation:

- partitioning or dividing up mathematics;
- deferring or displacing value or import;
- critiquing the system or recasting 'value'.

Whilst these trends are neither discrete nor uniformly deployed, the data supports their actuality as separate lines of argument, each of which is effected in a way which is cognisant of diversity and disparity amongst the purposes of mathematics education. These three rationalisation strategies will now be exemplified and discussed in turn.

6.3.1 Dividing Up Mathematics

The first strategy, partitioning, involves a division of mathematical learning into sections which are then judged to be of differing value. Although this partition can be variously configured, the data suggests that the dominant form of this strategy involves a demarcation between practical and nonconcrete mathematical learning, with algebra featuring regularly:

"…the thing is like, algebra and things like you don't really need that in life, do you really?" (lower grades GCSE student)

"That's the one thing I really struggle with, algebra… I suppose from a scientific point of view, or those people that need it… I'm sure that obviously it's a really useful tool, but… … I still see it as pointless." (adult GCSE learner G)

Sometimes the partition was articulated using hypothetical contexts such as employment scenarios where mathematics would or would not be useful:

"I just think that… it's important in some ways but in other areas it's not really that important." (borderline GCSE student)

"maybe if you're an accountant… or in finance, but… if you've got a calculator you should be alright."(borderline GCSE student)

Other demarcations observed included divisions between ages, or phases of schooling:

"I just don't like the way it's compulsory, like I think to a certain age it should be but I think, the stuff that comes up in tests now is pointless, really." (borderline GCSE student)

This strategy can also be discerned in the later parts of the undergraduates' narratives, for instance in Adam's insistence that he would still commend school mathematics to his friends:

"I'm still you know a champion for that side of things, I still tell them it is great, but university maths maybe not so much."

In each case, the positioning of a large section of mathematics education as less valuable devalues the study of mathematics as a whole, thus assuaging any threat that failure or difficulty might have to the learner's academic self-concept.

To exist and function effectively as a rationalisation strategy, partitioning must be broadly consistent and stable against the background of the adopting individual's experiences of mathematics education. Critical reading of the frequency of this strategy in the presented data therefore poses that partitioning must be advantaged by weaknesses and deficiencies in contemporary teaching and learning, which themselves arise out of tensions amongst the purposes of mathematics education. For instance, when working within the current foundation GCSE mathematics specifications, it is far easier to stress the functional nature of number-based skills such as working with decimals than to illustrate the purposes of the algebraic skills such as expanding brackets or applying the index laws; these tools are more readily deployed in the higher tier, on the other side of the borderline. This arrangement has led to a preponderance of so-called functional tasks involving money and finance, whilst the teaching of brackets and indices is more often served by rote learning and practice. If learners are further not included in discussions such as how learning algebra might help to develop logical thinking skills, how algebra is interrelated with arithmetic, or how an appreciation of the general and specific can inform democratic participation, then the purpose of learning algebra is likely to be cast solely in terms of roles, not goals; algebra is an unhelpful obstacle to obtaining the all-important C grade and so partitioning is an apt psychological defence. This may account in part for the frequency with which algebra was criticised, as presented in section 5.4.1.

6.3.2 Deferral of Importance

The second minimisation strategy, deferral, entails the learner claiming that mathematics will only be important to them at an unspecified point 'in the future'. This was most obviously present in the interviews of the GCSE students who included discursive markers such as 'later on in life' or 'when you're older'. One borderline student was even more explicit:

"I don't really use maths out of our maths lesson… maybe it will be more useful in the future?"

Whilst some learners might genuinely hold this form of opinion in a straightforward manner, it is probable that for others this position also constitutes a more immature instance of minimisation, wherein denial and rationalisation are deployed to manufacture a protective psychological distance. To wit, students who are studying for their GCSE examination are at an age where they are typically: handling money for themselves; exposed to raw figures and graphical summaries of statistical data in the media; considering the prerequisites of courses in further education and employment; and in some cases, involved in part-time employment. Given this background, adoption of the position that mathematics is only useful 'in the future' must be considered naïve, deliberate or both.

Again, a critical reading of deferral can pose that this form of minimisation is more readily open to learners when the staging of mathematics education involves an imbalanced presentation of certain roles and goals. In particular this strategy suggests that, in at least some cases, there exists a relative paucity of strategies connecting mathematical learning with activities perceived by learners to lie genuinely within their current spheres of activity. Such a deficit, when evaluated alongside the dominant discourse of mathematics as a gatekeeper subject, seems likely to lie at the root of many instances where mathematics is something which is only useful 'in the future'.

6.3.3 Critique

The third minimisation strategy observed in the data involved the learners critiquing the processes and traditions of mathematics education. One common way in which this strategy was deployed was to evince a claim that mathematics assessments rely too heavily on memory. Such an assertion begins to separate measured attainment from personal ability, moderating the impact of failure in examinations on a learner's self-image. Memory was stated as a concern by some learners within every group: one borderline GCSE learner complained that "there's a lot of stuff to remember, like how to add certain equations and, fractions and stuff" and memory was cited as one of the most challenging things about returning to the formal study of mathematics as an adult. Reliance on memory also seemed to be a significant concern for the undergraduates, most extensively in Mark's narrative:

"during an exam you've got so many definitions you're expected to remember, stuff from previous years as well, and just to be able to like, just regurgitate all

these random theorems and definitions they expect you to know is, just gets a bit… extreme."

Whilst the proper place of necessary memorisation in formal mathematical assessments is open to critical consideration, it is telling that this argument is present in all three sets of data, including the narratives of the undergraduates. There are few, if any, assessments alluded to in the data which would have necessitated extreme or incongruous amounts of memorisation; the demands of GCSE, A-level and university examinations in mathematics are comparable to equivalent assessments in other disciplines. Similarly, whilst abstractness may be an issue for some learners when memorising mathematical definitions or formulae, other subjects present their own demands, such as internalising the academic elements of music theory, remembering how to conjugate irregular verbs in a foreign language, or learning extended quotes from literature. In most cases in mathematics, memorisation is chosen on some level by each learner as either a deliberate strategy or, in the words of the undergraduate Adam, as a 'last resort'. Any attempt to devalue the relevance of attainment by claiming mathematics examinations require extreme memorisation thus involves an element of denial as well as rationalisation.

A second observed form of this appraising strategy involves an assertion that the import attached to mathematics as a subject is in some way unspecific or subjective; a clear example of this was offered by the lower grades GCSE student originally discussed in section 5.5.1, who offered that "I probably do think that maths is more important for getting a job than it is as a practical skill for the world… I do believe it's seen as a kind of competence thing." Similarly, one borderline peer of this student understood the role of mathematics as a gatekeeper subject to be subjective: "…it's just like a basic subject… it's a thing they've obviously chosen that's important we all learn… it's just the decision they made."

The notion that attainment in mathematics is used by society as a somewhat arbitrary marker of a more general aptitude or intelligence serves to insulate the learner's self-image in two ways: it diminishes specific concerns over any lack of success in mathematics whilst promoting the notion that there are other, equivalent avenues through which one may establish intellectual credibility and amass cultural capital.

Once again there is some critical cogency to this strategy; the social and cultural positions of mathematics as both a gatekeeper subject and a marker of general intellectual ability are in part received and traditional. Nevertheless, and as outlined in chapter one, there is a particular worth and potency to mathematical learning which has sustained these attributions, and so again this strategy involves both denial and rationalisation.

Through its deployment of a reflective critique this strategy, in any of its forms, is perhaps the most explicit of the three minimisation approaches detailed here in the way it considers the various goals and roles of mathematics education. Still, and for a third time, a critical reading of the frequency of this strategy speaks to an imbalance in the presentation of the purposes of mathematics education.

6.3.4 Discussion of Minimisation Strategies

There are a number of restrictions to the ideas and discussion offered above. For instance, these three minimisation strategies may be deployed in a vague or overlapping manner, and beyond this any psychological stresses about learning mathematics which contribute to developing a mathematical identity are undoubtedly conflated with and conjoined to broader concerns about academic self-concept. Further, identity has been conceptualised herein as complex and as perpetually being built and rebuilt; whilst some of these minimisation strategies undoubtedly endure beyond the context which originally led to their adoption, none of them are posited as stagnant or permanent positions. The layered nature of mathematical discourses may even lead to complexities within learners' mathematical identities which incorporate multiple, sometimes historical states of identity, and unrealised internal inconsistencies; indeed there is some evidence of this in some of the narratives as the learners attempt to express their developing opinions and experiences. Features of these minimisation strategies appear in some of the researched narratives even when the leading identity appears positively disposed towards learning mathematics and cognisant of multiple purposes.

Nevertheless, as a broad critical tool, the discussions within section 6.3 to this point explicate the data well in summary, addressing the research questions and speaking to a potential confusion of purposes invoked in contemporary mathematics education. Specifically, they hold that the esteem and cultural capital associated with mathematics, if not properly contextualised and developed against a fuller range of goals and roles, may actually be a harmful factor in many learners' constructions of mathematical identity and purpose. Less successful learners are at risk of adopting minimisation strategies which reject or devalue mathematics; meanwhile more successful learners are tacitly encouraged to build identities which, by being predicated on a limited understanding of what success in mathematics might mean, may not be sufficiently resilient to manage future transitions.

6.3.5 Purpose, Philosophy and Psychology

The discussion of identity construction and ego defence strategies above can further be understood as highlighting connections between philosophy and psychology within mathematics education research. In particular, the discussion above can be alternatively framed by drawing on research into achievement goals (Elliot 2005), particularly the concepts and findings espoused by Dweck (1986; 2000). Dweck explicates different learners' responses to failure by distinguishing between two forms of achievement goal: performance goals, based around competence and normative standards of attainment, and learning goals, centred on personal improvement and task mastery. Learners who focus on performance goals are more likely to exhibit low confidence and 'helpless' responses to failure than those who establish learning goals. This has a resonance with the preceding findings of this research. The purposes of mathematics education termed herein as 'goals' are often more in line with Dweck's notion of learning goals; if a learner wishes to develop their own personal numeracy or critical citizenship they are more focused on personal gain and application than abstract attainment. Conversely, the purposes listed as 'roles' are more strongly related to Dweck's performance goals; mathematics has been established to function as a gatekeeper and as a marker of intelligence through normative assessment which foregrounds interpersonal comparisons. It is of note to this critical research that related inquiry into achievement goals (Nicholls 1979) has considered equality in educational practice, arguing that conceptualising goals in terms of self-development promotes equal motivational opportunity.

Purpose in mathematics education is accordingly salient to the psychology of mathematics education as well as its philosophy. Strategies designed for improving attitude or mindset are thus at risk of being abrogated unless discourses of purpose are appropriately aligned and communicated. This connection speaks further to the implications of the social and political roles of mathematics education. It can be recognised that high stakes testing such as that surrounding GCSE mathematics in contemporary England not only involves a stressing of the roles of mathematics education at the potential expense of goals, but also actuates an implicit link to a behaviourist view of learning wherein it is supposed that linked outcomes for the teacher and learner will lead to contingent reinforcement (Ryan and Brown 2005, p.355).

Bourdieu (1998, p.28) described the judgements of mathematics as often being laid out with a "psychological brutality". This section has shown how this comment might be taken literally, by summarising how the data reports a number of clear psychological processes marshalled in response to apparent psychological attack. The next section will consider the consequences of these results, as well as ways in which present trends might be addressed and improved upon.

6.4 Critical Commentary on Contemporary Construction of Mathematical Purpose and Identity

As previously discussed in chapter two, any claim to critical theory implicates a dual purpose of description and transformation. To this end, this section will consider how the findings of this research might constructively inform the development and advancement of mathematics education in contemporary England. Expressly, whereas the preceding chapters have each identified and discussed specific elements of good practice relating to each studied cohort of learners, it is now necessary to consider how the main argument might gainfully speak to current practices of teaching and learning in mathematics.

In its broadest form, the principal argument of this thesis has been that the various goals and roles of contemporary mathematics education are not merely abstract components of ideologies for the attention of policy makers and educational researchers, but steering factors which meaningfully influence choices and contribute to the experiences of individual learners. Purpose impacts upon practice in myriad ways and thus philosophy is crucial in both steering mathematical trajectories and constructing mathematical identities; throughout the data individual learners' appreciations of the various goals and roles have been shown to have the power to enable or limit, to frustrate or inspire. However, discussions of the aims and objectives of mathematics education have seldom been found to be explicit or direct; instead purpose has been recurrently implied and inferred through the staging and grammar of mathematics teaching and learning. The term 'staging' is used here to denote how mathematics education and its attendant qualifications are introduced, supported, discussed both inside and outside of the classroom, structured and awarded power; the term 'grammar' takes account of the daily outworking and practices of mathematics education, its pedagogy, tropes and traditions.

The sway of the purposes of mathematics education on individual learners is arguably most visible in the data within the narratives of those who have transitioned between distinct communities of practice. In moving from school to adult education, or from school to undergraduate study, these learners have experienced different, somewhat dissonant grammars of mathematics education which have stemmed from separate appreciations of the purposes of learning mathematics. The consequent reactions observed of the learners further demonstrate that, whilst previous experiences can remain dominant in shaping mathematical identities, both positive and negative changes are possible in light of shifts in provision, pedagogy and presentation, wherein mathematical identities are formed and reformed in light of new experiences and understandings. The possibility of change and improvement thus tasks any critical commentary with establishing which presentations of mathematics might support the development of psychologically healthy, supportive and agentic mathematical identities.

The debates surrounding the purposes of mathematical education are involved and continually changing and it is outside of the scope of this work to make or defend any absolute judgements of relative merit or current significance. However, the data supports the advancement of two inter-related arguments. First, presentations of mathematics which recognise and foreground the role of the individual within a community of learners are more likely to lead to the development of supportive, agentic mathematical identities. Second, presentations of mathematics which more openly recognise and balance multiple goals and roles of mathematics education are more likely to lead to the development of resilient mathematical identities.

Arguments accentuating the need for agency and balance in learners' comprehensions of the purposes of mathematical learning explicate the positive experiences detailed in chapter three, where learners exposed to a new, inclusive and authorising presentation of mathematics found their mathematical activity validated; the new grammar of mathematical learning balanced the otherwise dominant role which had steered their trajectories to this point. The arguments offered above also make sense of the narratives constructed in chapter four, wherein the undergraduates did not successfully manage the shifts in the discourses surrounding the purposes of mathematical learning, nor the accompanying changes in the nature of mathematical activity and how success was defined. These arguments further take account of the minimisation strategies observed in chapter five and elsewhere, noting that such psychological mechanisms would be repeatedly challenged and disempowered by a balanced presentation of the purposes of mathematical learning.

From the beginning this thesis has critically considered the contemporary staging of mathematics education and all preceding criticisms continue to be upheld here in light of the data analysis. However, the call for a balanced, empowering presentation of mathematics also speaks to the grammar of the mathematics classroom and offers a number of challenges. Do current curricula sufficiently communicate the utility of all of the strands of mathematics, or do they support pupils in drawing distinctions between concrete and nonconcrete concepts? Do current practices of assessment suitably valorise effort and progress, or overstress the role of mathematics as an absolute measure with which pupils can compete and be compared? Do pedagogical choices consider every learner as a legitimate user of their own mathematics, or position most on the periphery of an inherited discipline? Perhaps most immediately at the time of writing, do the organisational, pedagogical and daily choices of teachers and schools balance the discourses imposed by the establishment of mathematics as a gatekeeper subject, or exacerbate the anxieties and concerns of students by reiterating and restating one role at the expense of all others?

Mathematics occupies a powerful place within the contemporary English education system, set apart from other subjects and awarded a particular respect. It is hoped that the stories of this thesis serve as a reminder that, if we are to promote positive mathematical identities and encourage progressive mathematical trajectories, this respect must be earned and given, and neither assumed nor forced.

6.4.1 Contributions to Knowledge and Areas for Future Research

This thesis has made a number of contributions to knowledge within mathematics education. Initially, within its individual data chapters, it has described and interpreted the experiences of an array of groups of learners, taking advantage in each case of a noted gap in the extant literature. In this way these three chapters contain local findings which add to current understanding and are of value to researchers in these specific areas. Subsequently as a whole it has gone further, offering a substantiated critical perspective on current debates and contemporary practice in mathematics education, and elucidating ways in which the philosophy of mathematics education might be awarded more attention and even connected to other fields of mathematics education research.

Even so, the epistemological and methodological natures of this research automatically suggest two avenues for future research which could further build on the methods and findings of this thesis. First, future confirmatory work involving learners in different contexts could support the grounded theory offered in this chapter. In particular, international comparisons would be of great value as they have the potential either to offer a supporting contrast or advance the arguments contained here in a fundamental manner. Second, the critical nature of this research advocates the implementation of the ideas presented herein. For example, and as alluded to in the previous section, this research would sustain the undertaking of an action research project that began with a considered balance of the purposes of mathematics education and then developed it into an alternative curriculum and empowering pedagogy which could be delivered and evaluated. In addition to these, there are a number of avenues of research which could further advance research into the philosophy of mathematics education. For instance, the discussion in section 6.3.5 above has tentatively shown how social psychology and philosophy might be understood to meet in discussions of purpose. There may be value in developing this intersection into a fuller theoretical framework by constructing and testing a shared vocabulary and understanding, so as to inform current debates and move on classroom practice.

6.5 Conclusion

In a final reflexive note, I offer here that it has been problematic at times succinctly describing this thesis to friends and colleagues; the 'philosophy of mathematics education' seems like a highly specialist field and sounds an esoteric one. Yet it is the contention of this work that the preceding discussions are necessary and important if we are to properly reconsider the simplest question of "why are we doing this?" in the current political climate.

It is frequently quoted that "all mathematical pedagogy, even if scarcely coherent, rests on a philosophy of mathematics." (Thom 1973, p. 204) I respectfully offer here that an analogous claim is that all mathematics education ultimately and fundamentally rests on assumptions about purpose. These assumptions might be implicit or explicit, considered or confused; they may be on the part of the learner, the teacher, the administrator or the policy maker. Regardless, in each and every case they are present and potent. The preceding data has shown that ignoring these notions of purpose exacerbates the risks of learners constructing negative mathematical identities, experiencing disjointed transitions between stages of education or even leaving mathematics behind at personal and national cost. Conversely, by exposing and critically questioning them we acquire the potential for ameliorative change.

As an area of human study and endeavour, it is indisputable that mathematics possesses many unique qualities and offers much which has been, is and will continue to be essential in supporting the function and progress of both individuals and society. However, both the subject itself and its place in society are continually evolving. The mathematics which someone would typically need to know for their job in 1963 is very different fifty years later in 2013; equally, the mathematics which an individual is exposed to in ‘everyday’ situations has also moved on. Mathematics education has an associated need to evolve and this stretches beyond shuffling curricula, raising expectations of performance or demanding increases in ‘standards’. To do this we must be more fully aware of the many purposes of mathematics education, how these purposes are communicated and executed and also the gains and harms which can arise out of the competing and co-existing goals and roles of mathematics education; only in this way can we better help others to navigate mathematics.

APPENDIX A: ADULT MATHEMATICS RESEARCH QUESTIONNAIRE

Thank you for taking part in this research. I'm looking at the reasons that people return to learning maths after spending some time away, and how they find it different learning maths as an adult, rather than as a child.

Please answer the questions by ticking whichever box or boxes best describe you. There is also space under each question if you want to explain something, or give an example of what you mean. The questionnaire should not take more than 10 minutes to complete.

All of the information collected will be treated anonymously. However, I am hoping to follow up this questionnaire with some short interviews. If you are willing to be contacted, please write your name below with a phone number or e-mail address.

☐ I AM NOT willing to be contacted for a short follow-up interview.

☐ I AM willing to be contacted for a short follow-up interview and my name is:

………………………………… Contact details: ……………………………...

SECTION ONE: ABOUT YOU

I am: ☐ Female ☐ Male

I am: ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ over 55

What type of course are you currently following?

☐ Adult Numeracy ☐ GCSE ☐ A-Level

Other ☐ (please specify):____

Before you started on this course, what qualifications did you already have *in maths*? (Tick all that apply.)

☐ None ☐ Numeracy (e.g. ALAN) ☐ GCSE

☐ CSE ☐ O-Level ☐ A-Level

Other ☐ (please specify):____

Before you started on this course, what qualifications did you already have *in other subjects*? (Tick all that apply.)

☐ None ☐ Adult Literacy (e.g. ALAN) ☐ GCSE ☐ CSE

☐ O-Level ☐ A-Level ☐ University Degree

Other ☐ (please specify):_______________________________________

Have you previously done an adult education course? YES/NO

If so, what course(s) have you done?

____

____

____

SECTION TWO: ABOUT YOUR DECISION TO TAKE A MATHEMATICS COURSE

Before you enrolled on this course, how long had you been considering taking a maths course?

☐ Only recently ☐ For a few months ☐ For about a year ☐ For significantly longer than a year

Which of these factors contributed to your decision to take a mathematics course? (Tick as many as you think apply.)

☐ I wanted to be able to help more with my children's schoolwork
☐ I wanted to learn more maths to help me get by at work
☐ I was encouraged to do it by my family
☐ I needed a qualification to help me get a promotion in the job I have at the moment
☐ I always felt like I had missed out on something at school
☐ I wanted to become more able to use numbers on my own in everyday life
☐ I needed a qualification to help me get onto another course
☐ A maths qualification is necessary for a job I want to apply for
☐ I was encouraged to do it by my friends
☐ I wanted to improve my chances of getting a new job
☐ I wanted to do it to help me develop in confidence
☐ I wanted to do it for pleasure

Other ☐ (please state): ____

Now draw a circle around the tick next to the factor that you think was the **most** important.

If you would like to add any more detail about how you made your decision, please write it here:

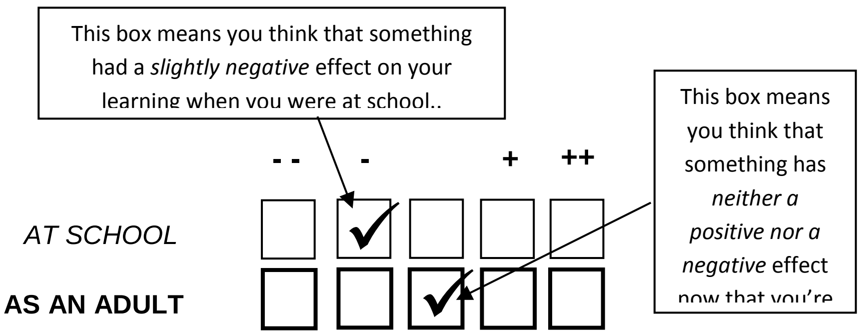
SECTION THREE: LEARNING MATHS AS AN ADULT

This section asks you to reflect whether something was **more helpful** to your learning when you were at school, or now, when you are learning maths as an adult.

Each question asks you whether a particular aspect of teaching had a **positive effect** or a **negative effect** on your learning at school, and now as an adult.

To answer each of these questions, tick one box in each row. If you think that a question doesn't apply to you, please leave it blank or write 'n/a' next to the boxes.

EXAMPLE:



a) How would you describe the effect of **your relationship(s) with your maths teacher(s)** on your learning?

	- -	-		+	++
AT SCHOOL	☐	☐	☐	☐	☐
AS AN ADULT	☐	☐	☐	☐	☐

b) How would you describe the effect of **the style(s) of teaching used by your maths teacher(s)** on your learning?

	- -	-		+	++
AT SCHOOL	☐	☐	☐	☐	☐
AS AN ADULT	☐	☐	☐	☐	☐

c) How would you describe the effect of **tests and assessments** on your learning?

	- -	-		+	++
AT SCHOOL	☐	☐	☐	☐	☐
AS AN ADULT	☐	☐	☐	☐	☐

d) How would you describe the effect of **computers and technology** on your learning?

	- -	-		+	++
AT SCHOOL	☐	☐	☐	☐	☐
AS AN ADULT	☐	☐	☐	☐	☐

e) How would you describe your experience of **having chances to work with other learners?**

	- -	-		+	++
AT SCHOOL	☐	☐	☐	☐	☐
AS AN ADULT	☐	☐	☐	☐	☐

f) How would you describe your experience of **working with real-world mathematical questions and tasks?**

	--	-		+	++
AT SCHOOL	☐	☐	☐	☐	☐
AS AN ADULT	☐	☐	☐	☐	☐

g) How would you describe your **overall experience of learning maths**?

	--	-		+	++
AT SCHOOL	☐	☐	☐	☐	☐
AS AN ADULT	☐	☐	☐	☐	☐

What would you say is the **most rewarding** thing about learning mathematics as an adult?

What would you say is the **most challenging** thing about learning mathematics as an adult?

If you could send one message back to yourself as a pupil in a maths class, what would it be?

Thank you very much for your time in completing this questionnaire. If you have any questions, my e-mail is R.M.Ward-Penny@warwick.ac.uk.

APPENDIX B: ETHICAL APPROVAL (ADULT LEARNERS)

If you are doing some empirical work for your dissertation, there will be a range of ethical issues that are raised. These include matters such as informed consent and confidentiality. They will be discussed in the Foundation Research Methods module. All students engaging in empirical research are required to complete an application for ethical approval. Please consult your supervisor when completing the form. **Forms should be submitted as soon as your research topic has been agreed.**

Taught Masters Dissertations and Projects:
APPLICATION FOR ETHICAL APPROVAL

Name of student: Robert Ward-Penny

Course: MA Educational Research Methods

Dissertation/Project title: What Might We Learn from the Prodigals? Adult Learners and Motivation in Mathematics Education

Supervisors: Peter Johnston-Wilder, Sue Johnston-Wilder

Participants: (if children, specify age range)
Adults currently enrolled on mathematical adult education courses.

Consent - will prior informed consent be obtained?

From participants? *YES/~~NO~~*

From others? *YES/~~NO~~*

Explain how this will be obtained. If prior informed consent is not to be obtained, give reason:

The research will take place in two stages: a questionnaire and follow up interviews. Adult education centres will be informed of the nature and design of the research, and will allow or disallow their students to take part as a cohort. Individual students who are allowed to take part will be provided with a questionnaire which will state clearly in writing that participation is optional, and also that names are not required so as to assure confidentiality. Students who are willing to take part in follow up interviews will be required to give their names, but their participation in both the questionnaire and interview is still optional. The start of the interview will contain a disclaimer, so that the individual gives informed consent.

Will participants be explicitly informed of the student's status? *YES/~~NO~~*

Confidentiality

Will confidentiality be assured? YES/~~NO~~

How will confidentiality be ensured?

Students who only complete the questionnaire will not give their name. Students who do for the purposes of follow up interviews will have their names changed in the write up. Centre names and locations will also be withheld, so as to give institutional confidentiality.

Protection of Participants

How is the safety and well being of participants to be ensured?

There are no immediate concerns about the safety or well being of participants – this project will take up very little of their time and if anything is likely to exhort them for returning to mathematics learning. Interviews should take place either by e-mail or on-site at the institution so there are no immediate health and safety concerns.

Is information gathered for participants of a sensitive or personal nature? ~~YES~~/NO

If yes, describe the procedure for (a) ensuring confidentiality

It's very unlikely that sensitive information will come up – however, if it does, it will be sensitively coded in any report, e.g.: "withdrew from education for family reasons", and names will be disguised or changed as described above.

(b) protecting participants from embarrassment or stress
See above.

Observational research

If observational research is to be carried out without prior consent of participants, please specify a) situations to be observed

There are no plans for observational research at this stage. If it becomes apparent that observing an adult education lesson would be insightful and possible, then observation will take place with subtlety and discretion as is normally the case with classroom observation. It would also be done closely in league with the institution and individual teacher concerned.

b) how will privacy and cultural and religious values of participants be taken into account?

Not applicable – see above.

Signed (Student): Date: 09/02/09

APPENDIX C: ETHICAL APPROVAL (UNDERGRADUATE LEARNERS)

Project title: **Exit Interviews – Exploring the Stories of Undergraduates Leaving Mathematics (Provisional Title)**

Supervisor: This is a joint project between the student, Robert Ward-Penny, Sue Johnston-Wilder (Warwick) and Clare Lee (Open). Sue will be acting in the dual role of researcher and supervisor for Robert. In addition, Robert will also have access to Dr. Peter Johnston-Wilder as a PhD supervisor.

Funding Body (if relevant): Robert is on an ESRC funded scholarship; otherwise this project is not funded.

Please ensure you have read the Guidance for the Ethical Conduct of Research available in the handbook.

Methodology

Please outline the methodology e.g. observation, individual interviews, focus groups, group testing etc.

This research is a phenomenological study designed to explore and report on the experiences of undergraduates who are reconsidering their relationship with mathematics at the end of their degree programme. Data collection will take the form of approximately eight to ten (depending on recruitment) individual, semi-structured interviews. Each of these should last approximately 45 minutes. These will involve questions about how the learner decided to take a mathematics degree, how their experiences of mathematics have changed, if at all, and what strategies they have used to inform their learning of mathematics.

Participants

Please specify all participants in the research including ages of children and young people where appropriate. Also specify if any participants are vulnerable e.g. children; as a result of learning disability.

The participants are final year students at XXXXXXXXXXXXXX. They have all taken part previously in an education module, XXXXXXXXXXXXXXXXXXXXXXXXXXXX. This means that they have already been involved in a significant period of self-reflection, and also that they have access to a range of terms and educational vocabulary which puts them in a unique position to express their ideas. (This does also invoke additional issues of bias, and these will be discussed in the write up.)

At the end of the module (run by Robert), thirteen students provisionally volunteered to be interviewed. This group will be contacted again, and the research explained to them in depth. They will then be asked whether they are still willing to take part.

Respect for participants' rights and dignity

How will the fundamental rights and dignity of participants be respected, e.g. confidentiality, respect of cultural and religious values?

For confidentiality, please see below. To protect the rights and dignity of the participants, Robert is not taking part in the interviews (as he has a role of power as course tutor) and will only contact the students as an organiser. This research will take place after he has done the course marking with the exception of the exam papers (which are anonymous).

The intention is also to perform the research relatively soon, so that it is not too close to the students' exams, and so that it doesn't eat into their revision time.

Privacy and confidentiality

How will confidentiality be assured? Please address all aspects of research including protection of data records, thesis, reports/papers that might arise from the study.

Pseudonyms will be used to protect the identities of the students in any reporting, and if any particularly sensitive issues arise, these could be disguised further by reporting incidents independently from an individual's main narrative.

Data recordings will be kept securely and without linked records of the students' names.

Consent - will prior informed consent be obtained?

- from participants? **Yes**/No from others? Yes/**No**

- explain how this will be obtained. If prior informed consent is not to be obtained, give reason: this will be obtained informally through the participants' decision to attend the interview, and through the description of the research in the invitation e-mail. Students will also sign an informed consent form at the point of interview.

- will participants be explicitly informed of the student's status?

Students are already aware of Robert's status as a PhD student. The nature of Sue and Clare's involvement will be detailed in the invitation e-mail.

Competence

How will you ensure that all methods used are undertaken with the necessary competence?

Both interviewers are experienced and have proven their competence. However, Robert will serve as a moderator of sorts, helping to strive for reliability and also looking out for any possible issues of this nature.

Protection of participants

How will participants' safety and well-being be safeguarded?

Please see above for a discussion of how confidentiality will be assured. No other issues of safety or well-being are foreseen, except possible issues of emotional response (see below).

Child protection

Will a CRB check be needed? Yes/**No** (If yes, please attach a copy.)

Addressing dilemmas

Even well planned research can produce ethical dilemmas. How will you address any ethical dilemmas that may arise in your research?

Initially any dilemmas could be discussed amongst us as a team of three researchers. If this did not give rise to a satisfactory solution, we could call on the wider support networks at both the University of Warwick and the Open University.

Misuse of research

How will you seek to ensure that the research and the evidence resulting from it are not misused?

This is a small-scale, exploratory study, and it is unlikely that the research will result in any findings that could be misused. For some discussion of this, please see 'integrity' below.

Support for research participants

What action is proposed if sensitive issues are raised or a participant becomes upset?

Initially, the interview could be paused, and a break in the proceedings could be offered. However, if the issues discussed were too emotive, we would stop the interview, and offer to wipe the recording and withdraw the participant from the research.

Integrity

How will you ensure that your research and its reporting are honest, fair and respectful to others?

To safeguard our individual and joint integrities, we will endeavour to hold each other accountable to appropriate standards in the way the research is written up: we will strive for transparency of method, so the limitations of our results are readily apparent, and we will also attempt to make sure that any quotes are placed in context so that they evoke the original meaning of the participants.

What agreement has been made for the attribution of authorship by yourself and your supervisor(s) of any reports or publications?

This has been conceived, and will be undertaken and written up as a joint project between the three named parties.

Other issues?

Please specify other issues not discussed above, if any, and how you will address them.

Signed

Research student	Date
	12th February 2010

APPENDIX D: ATTITUDES TOWARDS MATHEMATICS QUESTIONNAIRE

This questionnaire contains 40 statements about learning mathematics. Please circle the word or words which best describe your opinion of each statement. There are also two open-ended questions at the end.

All of the information collected will be treated anonymously and confidentially. This means that your teacher will not read your individual responses, so please answer the questions as honestly as you can.

Thank you for taking part in this research.

I am ☐ Male ☐ Female

What set are you in for mathematics? ☐

---

1. Mathematics is a very worthwhile and necessary subject.

Strongly Disagree Disagree Neutral Agree Strongly Agree

2. I want to develop my mathematical skills.

Strongly Disagree Disagree Neutral Agree Strongly Agree

3. I get a great deal of satisfaction out of solving a mathematics problem.

Strongly Disagree Disagree Neutral Agree Strongly Agree

4. Mathematics helps develop the mind and teaches a person to think.

Strongly Disagree Disagree Neutral Agree Strongly Agree

5. Mathematics is important in everyday life.

Strongly Disagree Disagree Neutral Agree Strongly Agree

6. Mathematics is one of the most important subjects for people to study.

Strongly Disagree Disagree Neutral Agree Strongly Agree

7. Studying GCSE mathematics will be helpful no matter what I go on to do at college or in sixth form.

Strongly Disagree Disagree Neutral Agree Strongly Agree

8. I can think of many ways that I use maths outside of school.

Strongly Disagree Disagree Neutral Agree Strongly Agree

9. Mathematics is one of the subjects I fear the most.

Strongly Disagree Disagree Neutral Agree Strongly Agree

10. My mind goes blank and I am unable to think clearly when working with mathematics.

Strongly Disagree Disagree Neutral Agree Strongly Agree

11. Studying mathematics makes me feel nervous.

Strongly Disagree Disagree Neutral Agree Strongly Agree

12. Mathematics makes me feel uncomfortable.

Strongly Disagree Disagree Neutral Agree Strongly Agree

13. I am always under a terrible strain in maths lessons.

Strongly Disagree Disagree Neutral Agree Strongly Agree

14. When I hear the word mathematics, I have a feeling of dislike.

Strongly Disagree Disagree Neutral Agree Strongly Agree

15. It makes me nervous to even think about having to do a mathematics problem.

Strongly Disagree Disagree Neutral Agree Strongly Agree

16. Mathematics does not scare me at all.

Strongly Disagree Disagree Neutral Agree Strongly Agree

17. I have a lot of self-confidence when it comes to mathematics.

Strongly Disagree Disagree Neutral Agree Strongly Agree

18. I am able to solve mathematics problems without too much difficulty.

Strongly Disagree Disagree Neutral Agree Strongly Agree

19. I expect to do fairly well in maths.

Strongly Disagree Disagree Neutral Agree Strongly Agree

20. I am always confused in my mathematics lessons.

Strongly Disagree Disagree Neutral Agree Strongly Agree

21. I feel a sense of insecurity when attempting mathematics.

Strongly Disagree Disagree Neutral Agree Strongly Agree

22. I learn mathematics easily.

Strongly Disagree Disagree Neutral Agree Strongly Agree

23. I am confident that I could learn more difficult mathematics in the future.

Strongly Disagree Disagree Neutral Agree Strongly Agree

24. I have usually enjoyed studying mathematics in school.

Strongly Disagree Disagree Neutral Agree Strongly Agree

25. Mathematics is dull and boring.

Strongly Disagree Disagree Neutral Agree Strongly Agree

26. I like to solve new problems in mathematics.

Strongly Disagree Disagree Neutral Agree Strongly Agree

27. I would prefer to do work in maths than to write an essay.

Strongly Disagree Disagree Neutral Agree Strongly Agree

28. I would like to avoid using mathematics in college or sixth form.

Strongly Disagree Disagree Neutral Agree Strongly Agree

29. I really like mathematics.

Strongly Disagree Disagree Neutral Agree Strongly Agree

30. I am happier in a maths lesson than in any other lesson.

Strongly Disagree Disagree Neutral Agree Strongly Agree

31. Mathematics is a very interesting subject.

Strongly Disagree Disagree Neutral Agree Strongly Agree

32. If extra maths had been offered as an option subject, I would have chosen it.

Strongly Disagree Disagree Neutral Agree Strongly Agree

33. I am going to put a lot of effort into my GCSE Mathematics.

Strongly Disagree Disagree Neutral Agree Strongly Agree

34. The challenge of maths appeals to me.

Strongly Disagree Disagree Neutral Agree Strongly Agree

35. I think studying advanced mathematics is useful.

Strongly Disagree Disagree Neutral Agree Strongly Agree

36. I believe studying maths helps me with problem solving in other areas.

Strongly Disagree Disagree Neutral Agree Strongly Agree

37. I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in maths.

Strongly Disagree Disagree Neutral Agree Strongly Agree

38. I am comfortable answering questions in maths lessons.

Strongly Disagree Disagree Neutral Agree Strongly Agree

39. Being good with maths could help me in jobs in the future.

Strongly Disagree Disagree Neutral Agree Strongly Agree

40. I believe I am good at solving maths problems.

Strongly Disagree Disagree Neutral Agree Strongly Agree

How do you think mathematics might be useful for *you* in the future?

Schools usually insist that every pupil takes GCSE mathematics. Why do you think everyone learns mathematics at school?

ALL of this information will be treated anonymously. However, this questionnaire is being followed up with some short interviews later this term. If you are willing to be interviewed, please write your name below.

☐ I AM NOT willing to be contacted for a short follow-up interview.

☐ I AM willing to be contacted for a short follow-up interview and my name is:

....

APPENDIX E: ETHICAL APPROVAL (BORDERLINE AND LOWER GRADES LEARNERS)

Project title: Researching the Mathematical Identities of GCSE Students

Supervisors: Dr. P.J. Johnston-Wilder and Mrs. S. J. Johnston-Wilder

Funding Body: I hold an ESRC Scholarship at the Institute.

Please ensure you have read the Guidance for the Ethical Conduct of Research available in the handbook.

<u>Methodology</u>

Please outline the methodology e.g. observation, individual interviews, focus groups, group testing etc.

The first stage of the research will involve a brief questionnaire being administered to groups of pupils. This will primarily contain approximately 35 statements such as “Mathematics is a worthwhile subject” with five-point Likert-type response boxes. The questionnaire will be based on the existing “Attitudes towards mathematics inventory” tool, with some adjustments for language and the English context. This questionnaire will be piloted with a small group of learners before its main use.

The second stage of the research will involve short (approx 10 to 15 minute) individual, semi-structured interviews following up responses of a small number of pupils, exploring some of the issues raised in the questionnaire in more depth and developing the content validity of the research.

<u>Participants</u>

Please specify all participants in the research including ages of children and young people where appropriate. Also specify if any participants are vulnerable e.g. children; as a result of learning disability.

The participants for the first questionnaire stage will be pupils in secondary school Year 10 (ages 14-15). I intend to approach six schools with varying social and educational contexts and ask each of them for access. Where schools agree, pupils will be identified through their mathematics classes, and pupils in ‘borderline’ classes (i.e. C/D grades) and ‘bottom sets’ (i.e. F/G grades) will be invited to undertake the questionnaire as a class, in the presence of their regular teacher. Pupils will be given the opportunity individually not to take part if they so choose.

The questionnaire will be anonymous, although there will be a section at the end where pupils can add their name if they are willing to be interviewed in the future. Participants for the second stage of the research will be selected from this subgroup, subject to negotiation with their teachers.

Participants who have expressed particularly interesting or resonant views will be selected, although there will also be an attempt to ensure that the pupils chosen are broadly representative in terms of salient characteristics such as gender.

Respect for participants' rights and dignity

How will the fundamental rights and dignity of participants be respected, e.g. confidentiality, respect of cultural and religious values?

Pupils will be in a position to 'opt in' to the research at each stage: the nature of the research will be explained before they complete the questionnaire; participation is voluntary; only those who explicitly choose to offer themselves for interview will be considered.

Data will be handled securely and confidentially, and when the research is written up pupils and schools will be anonymised. I will offer each school a summary of their results; this will consist of the quantitative results of the questionnaire, not the interview data, since the latter may be traced back to participating pupils and compromise anonymity.

It is most likely that no religious or cultural views will be explicitly touched upon in this research due to the nature of the subject matter.

There will be some impact on the pupils' mathematical education, although this is intended to be minimal. Both stages of the research are brief. The research is targeted at Year 10 pupils rather than Year 11 pupils since this should cause the least disruption to exams. Further, this study will take part in the Summer term; school will be asked to select a convenient time frame for access to minimise disruption even further.

Privacy and confidentiality

How will confidentiality be assured? Please address all aspects of research including protection of data records, thesis, reports/papers that might arise from the study.

Data will be stored securely. Transcript files will be labelled with identifying codes, not names, and any names invoked in the interviews will be removed before storage. When the research is written up for the thesis and/or publication schools and pupils will be anonymised, with pseudonyms being used where appropriate.

Consent - will prior informed consent be obtained?

- from participants? Yes

Verbal consent will be obtained from the pupils for stage one. This will be gathered after a brief description of the research with each of the class groups. As stated above, pupils will be allowed to choose not to complete the questionnaire, and it will be made clear that there is no connection with any assessment or school reward or sanction scheme. Pupils will give written consent to be interviewed at end of the questionnaire, and this will be checked at the start of each interview.

from others? Yes

Written consent will be gathered (most likely in the form of e-mails) from appropriate gatekeepers in the school, and further verbal consent from each class teacher.

- will participants be explicitly informed of the student's status?

Yes, and the nature of this research as part of my PhD will be made explicit.

Competence

How will you ensure that all methods used are undertaken with the necessary competence?

I have experience with conducting both questionnaires and interviews in the secondary school environment. Further, my supervisors are being kept informed at every stage of the research and will monitor my progress.

Protection of participants

How will participants' safety and well-being be safeguarded?

Please see above for a discussion of how confidentiality will be assured. No other issues of safety or well-being are foreseen. There is an outside chance that the interview could involve some minor emotional responses. In such an instance I would pause the interview, and give the pupil a chance to withdraw or take a break before continuing.

Child protection

Will a CRB check be needed? No (If yes, please attach a copy.)

I already hold a recent CRB in my role as a PGCE tutor at the University of Warwick; this is deemed sufficient by most schools and will be presented on entry.

Addressing dilemmas

Even well planned research can produce ethical dilemmas. How will you address any ethical dilemmas that may arise in your research?

Initially I would discuss any issues with my supervisors. If this did not bring about a satisfactory solution I would call on the wider support network at the university.

Misuse of research

How will you seek to ensure that the research and the evidence resulting from it are not misused?

It is difficult to conceive of a way in which this research could be misused, other than to criticise a particular pupil or school, or to make unhelpful contrasts between the schools. This will be made impossible by the privacy and confidentiality measures described above.

Support for research participants

What action is proposed if sensitive issues are raised or a participant becomes upset?

If this was to happen during the interview, then the interview could be paused, and a break in the proceedings could be offered. However, if the issues discussed were too emotive, I would stop the interview, and offer to wipe the recording and withdraw the participant from the research.

If this was to happen during the questionnaire (which seems very unlikely given the nature of the content) I would suggest that the pupil withdraws from the first stage of the research.

Integrity

How will you ensure that your research and its reporting are honest, fair and respectful to others?

Individual summaries of each school's results will be given an agreed individual in each institution as a measure of thanks, but also to allow a 'right to reply'. I will endeavour to make sure that the qualitative data is analysed in accordance with good practice, explicitly taking note of the limitations of my interpretations and ensuring that quotes are always offered in context. My supervisors will hold me accountable in these regards, and I will make the original data accessible to them if they wish to challenge me in any way.

I have no strong personal connections with any of the schools that I am selecting to invite into this research and so in this sense I have no agenda, and no predetermined bias towards or against any of the schools.

What agreement has been made for the attribution of authorship by yourself and your supervisor(s) of any reports or publications?

This research is primarily conceived of as contributing to my thesis, which will be presented under my own name.

Other issues?

Please specify other issues not discussed above, if any, and how you will address them.

Signed: Research student Date: 1st April 2011

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