The Evaluation of the Antimicrobial Self-Assessment Toolkit for NHS Trusts

A thesis submitted to The University of Manchester for the degree of Doctor of Philosophy in the Faculty of Medical and Human Sciences

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Abstract

Introduction: The Antimicrobial Self-assessment Toolkit for Acute NHS Trusts (ASAT) was developed by a pharmacist reference group of an Advisory Non-Departmental Public Body on Antimicrobial Resistance and Healthcare Associated Infections (ARHAI). It was developed in conjunction with the Department of Health. The primary purpose of the ASAT is to identify and to measure the methods of implementation of antimicrobial stewardship programmes in acute NHS trusts. The face validity was previously tested by ARHAI. The overall aims of this programme of work were to investigate the validity of the ASAT and to make iterative changes to improve its validity. Ethical approval was not required for this PhD project because it was categorised as service evaluation by the LREC. Also, ethical approval from the University of Manchester Research Ethics Committee was deemed unnecessary at the time of the PhD project due to the nature of the data collected.

Methods: A mixed methodology approach utilising a sequential exploratory strategy was used to investigate the validity of the ASAT. This PhD project was composed of four sequential studies which resulted in iterative changes to the ASAT, that is, from ASAT v15a to ASAT v18. In Study 1, cognitive interviews were conducted with eight antimicrobial pharmacists in order to investigate the content validity of ASAT v15a. In Study 2, both cognitive interviews and semi-structured interviews were conducted with 10 clinical microbiologists in order to investigate the content validity of ASAT v16. In Study 3, Rasch modelling and analyses using the Partial Credit Model (PCM) were conducted on the responses to ASAT v17 from 33 NHS trusts across England. In Study 4, simple OLS regression analyses were conducted using the NHS trust *'ability'* estimates or calibrations and *Clostridium difficile* (CDI) rates of participating NHS trusts in order to investigate model fit and the predictive validity of the ASAT.

Results: The cognitive interviews conducted in study 1 indicated that AMPs encountered cognitive difficulties along the cognitive processing pathway in response to ASAT v15a. These difficulties included comprehension in 27 (32.5%) questions and response generation/formatting in 13 (15.7%) questions. Also respondents indicated that the role of clinical microbiologists in ASPs was underrepresented in ASAT v15a. The interviews conducted in Study 2 were confirmatory in nature as they reflected the findings of Study 1. For example terms such as *'formulary'* and *'policy'* were misinterpreted by respondents. Rasch modelling and analysis showed that there were items within ASAT v17 which were underfitting and overfitting the Partial Credit Model. Item fit was investigated after removal of these items which resulted in improved fit for domains 2 and 5. ASAT v18 was developed after these analyses and was included items that were productive for measurement. On examination of the OLS regression analyses conducted in Study 4, it was seen that there was poor model fit and very limited predictive validity of the model.

Conclusion: The iterative methodology utilised to investigate the validity and subsequently improve the ASAT was effective in establishing content and construct validity. However, the predictive validity of the ASAT was limited. This may be due to the outcome variable chosen for the OLS regression modelling. A more sensitive outcome measure such as compliance to treatment or prophylaxis guidelines may have been more effective at establishing predictive validity. The findings of this programme of work highlighted that there is further work required to validate the ASAT such as the determination of the appropriate weights and scores for ASAT domains and also the determination of the appropriate outcomes measures to determine the efficacy of ASPs. It is recommended that further validity testing should be conducted before a further iteration of the ASAT is used as a set of quality standards or as a hospital benchmarking tool.

Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

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Dedication

To my late great grandfather Gilbert Walters and also to my late grandmother Muriel Elaine Boyce
Thank you for all you love and kindness

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About the author

Chantelle Bailey has worked at the University Hospitals of South Manchester as a Regional Clinical Audit Coordinator where she coordinated the clinical audit programme for the departments of Cardiothoracic Surgery and Cardiology. She has led several local and regional clinical audit projects which specifically targeted the provision of services for patients with myocardial infarctions and lung cancer. Other audit projects included the Myocardial Infarction National Audit Project (MINAP), Northwest Quality Improvement Programme for Cardiac Interventions (NWQIP) which focused on collating clinical data on patients receiving percutaneous coronary interventions (angioplasty) and also the Regional Northwest Cardiac Study which was conducted in conjunction with the University of Manchester.

Chantelle Bailey obtained her MSc in Biomedical Science (Cellular Pathology) from the Manchester Metropolitan University in 2008. Subsequently, she undertook a secondment position at the National Institute for Health and Clinical Excellence (NICE) as an Audit Development Analyst within the Implementation Directorate. Within this role she conducted analyses on the four types of guidelines or guidance produced by NICE. These guidelines included clinical guidelines (including short clinical guidelines), interventional procedures, health technology appraisals and also public health guidance. During her time at NICE, she had the opportunity to contribute to relevant research and evaluation projects in order to ensure that the audit tools from NICE was based on the best available evidence and also met the needs of the end-users.

During her PhD programme, she successfully managed a 6-month research project for NHS Diabetes and Kidney Care under the management and direction of Dr Grace Sweeney. This research study specifically evaluated the impact of Paediatric Network Coordinators on national service provision and service delivery for children and young people with diabetes. The findings of this study were presented at the Diabetes UK Professional Conference in March 2011.

Publications and Presentations

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Project title: Evaluation of the Self-Assessment Antimicrobial Toolkit for NHS Trusts (ASAT).
Abstract submitted and accepted for poster presentation at the Northwest Antibiotic Pharmacists Group (NWAPG) Conference 2010.

List of Abbreviations

A&E	Accident and Emergency
ABS	Antibiotic Strategies International
AMP	Antimicrobial Pharmacist
AMR	Antimicrobial Resistance
AMS	Antimicrobial Stewardship
ARHAI	Antimicrobial Resistance and Healthcare Infections Sub-group
ARPAC	Antibiotic Resistance, Prevention and Control
ASAT	Antimicrobial Self-assessment Toolkit for Acute NHS Trusts
ASP(s)	Antimicrobial Stewardship Programmes
ATC	Anatomical Therapeutic Chemical
BNF(c)	British National Formulary (for children)
BSAC	British Society of Antimicrobial Chemotherapy
CAP	Community-acquired pneumonia
CBA	Controlled before and after study
CCT	Controlled clinical trial
CDI	*Clostridium difficile* infection
CM	Clinical microbiologist
CPSG	Clinical Prescribing Sub-group
D&TC	Drugs and Therapeutics Committee
DDD	Defined Daily Dose
DGH	District General Hospital
DH	Department of Health
DIPC	Director of Infection Prevention and Control
EARSS	European Antimicrobial Resistance Surveillance System
ECDC	European Centre for Disease Prevention and Control
EPOC	Cochrane Effective Practice and Organisation of Care Review Group
ESAC	European Surveillance of Antibiotic Consumption
ESBL	Extended Spectrum *β*-lactamase
ESCMID	European Society of Clinical Microbiology and Infectious Diseases
EU	European Union
EUCAST	European Committee on Antimicrobial Susceptibility Testing
GRE	Glycopeptide-resistant *Enterococci*
HCAI(s)	Healthcare-associated Infection(s)
HPA	Health Protection Agency
HPI	Hospital Pharmacy Initiative
ICU	Intensive Care Unit
IDSA	Infectious Disease Society of America
IRT	Item Response Theory
ITS	Interrupted time series
KPC(s)	*Klebsiella pneumoniae* carbapenemase(s)
KPI(s)	Key priorities for implementation
MDT	Multidisciplinary Team
MIC	Minimum Inhibitory Concentration
MRSA	Meticillin-resistant *Staphylococcus aureus*
MSSA	Meticillin-sensitive *Staphylococcus aureus*
NHS	National Health Service
NICE	National Institute for Health and Clinical Excellence
NWAPG	Northwest Antibiotic Prescribing Group
OLS	Odd Least Squares
OPAT	Outpatient Parenteral Antibiotic Therapy
PCM	Partial Credit Model
RCT	Randomised controlled trial
SACAR	Specialist Advisory Committee on Antimicrobial Resistance
SHA	Strategic Health Authority
SHEA	Society for Healthcare Epidemiology of America
SMAC	Standing Medical Advisory Committee
TATFAR	Transatlantic Taskforce on Antimicrobial Resistance

List of Abbreviations *(cont'd)*

TDM	Therapeutic Drug Monitoring
VRE	Vancomycin-resistant *Enterococci*
WHO	World Health Organisation
WTE	Whole time equivalent

Glossary

TERM	DEFINITION
Antimicrobial	It is an agent of drug that is capable killing microorganisms or suppressing their replication or growth.
Antimicrobial formulary	A formulary is a limited list of drugs available on prescription. It may include information about available formulations (by route of administration), dosing instructions and advice about drug safety or interactions but it does not include detailed guidance for use.
Antimicrobial guidelines	Guidelines provide advice about what drug should be prescribed for a specific clinical condition. These guidelines should be evidence-based and prepared in line with best practice recommendations for treatment of infections.
Antimicrobial policy	This is a set of statements about an organisation's strategy for promoting prudent antimicrobial prescribing.
Antimicrobial resistance	Antimicrobial resistance is resistance of a microorganism to an antimicrobial medicine to which it was previously sensitive.
Antimicrobial strategy	A plan of action such as an antimicrobial educational strategy which is designed to achieve a long-term or overall aim such as prudent antimicrobial prescribing.
Antimicrobial stewardship	The optimal selection, dose and duration of an antimicrobial that result in the best clinical outcome for the treatment or prevention of infection, with minimal impact on subsequent resistance development.
Antimicrobial stewardship committee	An antimicrobial stewardship committee should have multidisciplinary representation e.g. antimicrobial pharmacists, infection control nurses, infectious disease physicians and clinical microbiologists. Each member is given roles and responsibilities collectively for the implementation of antimicrobial policies.
Antimicrobial stewardship programmes	These are composed of the organisational structures and action plans required to implement antimicrobial stewardship. Organisational structures can include formulary restriction, computerised decision programmes, prior approval, education and audit.
Antimicrobial ward round	The primary purpose of the antimicrobial ward round is to rationalise antimicrobial therapy in line with, hospital guidelines, laboratory data and available evidence. The antimicrobial ward round should be composed of the antimicrobial pharmacist and a microbiology consultant or registrar.
Healthcare associated infections	Infections that are acquired in hospitals or as a result of healthcare interventions

CHAPTER 1:

Background and Literature review

1 INTRODUCTION

The thesis examines the validity of the Antimicrobial Self-Assessment Toolkit for NHS Acute Trusts (ASAT) which was designed to evaluate antimicrobial stewardship programmes (ASPs) in NHS trusts. The programme of work was conducted over four sequential studies where the findings of each study were used to modify and improve the ASAT. These studies were conducted utilising a sequential exploratory strategy. The first two stages of this strategy were qualitative in nature and were conducted using cognitive interviews with antimicrobial pharmacists in Study 1 using ASAT v15a *(Appendix XXVIII)*. Both cognitive interviews and semi-structured interviews were conducted with clinical microbiologists in Study 2 using ASAT v16. Both Study 1 and Study 2 were conducted primarily within the Northwest Strategic Health Authority (SHA). The next two stages, that is, Study 3 and Study 4, were quantitative in nature and were conducted using Rasch modelling and OLS linear regression modelling on actual ASAT scores (responses) from 33 NHS trusts which represented 58 hospitals across England. These studies were conducted utilising ASAT v17 and ASAT v18 respectively. Cognitive and semi-structured interviews have been previously used to test the validity of questionnaires. However, utilising Rasch modelling was novel because a questionnaire evaluating the organisational implementation methods for antimicrobial stewardship has not been investigated previously using this methodology.

Chapter 1 presents a brief description of ASAT v15a which contains seven domains. These domains are antimicrobial management, operational delivery of an antimicrobial strategy, risk assessment for antimicrobial chemotherapy, clinical governance, antimicrobial pharmacist and also patients, carers and the public. Also, this chapter presents a brief description of the development of ASPs both nationally and internationally. Also, presented in this chapter is the rationale for hospital-based ASPs such as reduction of antimicrobial resistance (AMR). The evidence base underpinning ASAT v15a is also presented which was conducted prior to the start of this programme of work. This literature review evaluated and critiqued this evidence base and was also conducted to ensure that the ASAT comprised of effective implementation methods of hospital-based ASPs. The findings from the literature

review were used to further develop and improve the ASAT and also to guide this programme of work.

1.1 Ambiguity of terminology

One of the barriers to evaluating the evidence which underpins ASPs was the ambiguity of terminology found in the literature. Numerous terms were used to describe *'antimicrobials'*, *'antimicrobial stewardship'* and *'antimicrobial stewardship programmes'*. The terms used to describe *'antimicrobial(s)'* in the literature were as follows:

- antibiotic(s)
- anti-infective(s)

The term *'antimicrobial(s)'* will be used to describe all of the above terms unless the text was sourced from direct quotes. The terms used to describe *'antimicrobial stewardship'* were as follows:

- antibiotic/antimicrobial optimisation
- optimal antibiotic/antimicrobial prescribing
- rational antibiotic/antimicrobial prescribing
- prudent antibiotic/antimicrobial prescribing

The phrase *'antimicrobial stewardship'* will be used to describe all of these terms. The terms used in the literature to describe antimicrobial stewardship programmes were as follows:

- antibiotic/antimicrobial restriction programme
- antibiotic/antimicrobial control programme

The phrase *'antimicrobial stewardship programmes'* will be used to describe the above terms. The term *'antimicrobial stewardship committee'* was used to describe local multidisciplinary committees which had a pivotal role in antimicrobial policy and guideline development. This term was also used to describe multidisciplinary ward rounds which were usually composed of pharmacists and microbiologists. In the literature, ward rounds were also described as an *antimicrobial utilisation committee'.* The term *'antimicrobial ward rounds'* will be used to describe ward-facing multidisciplinary teams in this chapter and the term *'antimicrobial stewardship committee'* will be used to describe multidisciplinary teams which have the remit of antimicrobial policy and guidelines development. Another example of ambiguity of terminology found in the literature occurred in instances where terms were used to

describe antimicrobial policies and antimicrobial guidelines. Many studies used these terms interchangeably or used the term *'policy'* to refer to the guideline and *vice versa*.

1.2 Antimicrobial stewardship

Antimicrobial stewardship (AMS) is not a new concept. In the 1980's, Dr Dale Gerding first described the concept of rational antibiotic prescribing as *'antibiotic stewardship'.*[1] The term *'antibiotic'* refers to a chemical substance produced by a microorganism that kills or inhibits the growth of another organism. The term antimicrobial refers to a substance (either naturally occurring or synthetic) that is harmful to microorganisms by either killing or inhibiting their growth.[2] The term *'antimicrobials'* also encompasses *'antibiotics'*, therefore for the purpose of this current literature review *'antimicrobial stewardship'* will be used instead of *'antibiotic stewardship'*. It can be defined as the optimal selection, dose and duration of an antimicrobial that result in the best clinical outcome for the treatment or prevention of infection, with minimal impact on subsequent resistance development.[3] This definition is very similar to the definition of prudent antimicrobial prescribing provided by The Interdepartmental Steering Group on Resistance to Antibiotics and other Antimicrobial Agents (Clinical Prescribing Sub-group) in 2001.[4] This sub-group defined prudent antimicrobial prescribing as:

'The use of antimicrobials in the most appropriate way for the treatment or prevention of human infectious diseases, having regard to the diagnosis (or presumed diagnosis), evidence of clinical effectiveness, likely benefits, safety, cost (in comparison with alternative choices), and propensity for the emergence of resistance. The most appropriate way that implies that the route, dose, frequency and duration of administration have been rigorously determined.'

The primary goal of AMS is to optimise clinical outcomes while minimising unintended consequences of antimicrobial use, including toxicity, the selection of pathogenic organisms (such as *Clostridium difficile*), and the emergence of resistance. The secondary goal of AMS is to reduce healthcare costs without adversely impacting on the quality of care.[5] ASPs are composed of the organisational structures and interventions required to implement AMS in hospitals.[5] ASPs are briefly discussed below in section 1.3.

1.3 Antimicrobial stewardship programmes

In 1998, the notion of a dedicated programme to improve antimicrobial prescribing was first reported by Briceland and his colleagues.[6;7] They described an *'antimicrobial streamlining programme'* which was a co-ordinated interdisciplinary approach between an infectious disease physician (ID physician) and a clinical pharmacist. Many studies have described a similar approach to antimicrobial prescribing, utilising terms such as *'prudent antimicrobial prescribing'*, *'optimal antimicrobial prescribing'* and also *'antimicrobial stewardship'* interchangeably. ASPs are composed of the organisational structures and action plans required to implement AMS in hospitals.[5] More recently, ASPs have developed and now it has become an established method of promoting prudent antimicrobial prescribing in hospitals.

There are several methods of implementation of ASPs in hospitals, which aim to minimise any unwanted effects of antimicrobial therapy. There is consensus in the literature regarding the interventions that hospitals should use to implement ASPs.[8-10]

Davey et al (2005) describes and categorises these interventions as restrictive, persuasive and structural.[11] Examples of restrictive interventions included expert approval of restricted drugs or pre-authorisation, removal of high-risk antimicrobials from ward stocks, automatic stop orders and computerised order forms. Persuasive interventions included prescriber education, antimicrobial prescription review and recommending changes to antimicrobial therapy (if required), reminders, clinical guidelines, audit and feedback, care pathways and opinion leaders. Structural interventions included therapeutic drug monitoring and susceptibility testing. The composition and nature of these interventions undertaken by hospitals was dependent on the contextual setting of hospitals and also the availability of resources to support ASPs. Also, it has been suggested that hospitals should consult and establish close links with infection control programmes.[5;12]

Guideline producing bodies such as the Department of Health and other equivalent organisations internationally have published recommendations and position statements which have focused on AMS and infection prevention and control *(see table 1.1)*.

Table 1.1 - Published guidelines targeted at the reduction of AMR and promoting infection control in hospitals mapped to ASAT Domains

GUIDELINES/REPORTS/POSITION STATEMENTS (AMR/IC-RELATED)							
Guidelines or reports or position statements	**ASAT DOMAINS**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
The Path of Least Resistance (1998)[13]		✓			✓		
Optimising the clinical use of antimicrobials (2001)[4]		✓			✓		
Winning Ways (2003)[14]		✓					
Antimicrobial Policy and Practice in Scotland (2005)[15]	✓	✓	✓	✓	✓		
ARPAC Consensus report (2005)[16]	✓	✓		✓	✓	✓	
The Best Medicine (2007)[17]		✓	✓	✓	✓	✓	✓
Saving Lives (2007)[18]	✓	✓		✓	✓	✓	
SACAR Antimicrobial Framework (2007)[19]	✓	✓		✓	✓		
IDSA/SHEA Antimicrobial Stewardship guidelines (2007)[5]	✓	✓		✓	✓	✓	
HCAIs: What else can the NHS do? (2007)[20]	✓		✓	✓			

Table 1.1 *(cont'd)* - Published guidelines which are targeted at the reduction of AMR and promoting infection control in hospitals

GUIDELINES/REPORTS/POSITION STATEMENTS (AMR/IC-RELATED)							
Guidelines or reports or position statements	**ASAT DOMAINS**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
The Health and Social Care Act (2008)[21]	✓	✓		✓	✓		
***Clostridium difficile* infection: how to deal with the problem (2009)[22]**	✓	✓		✓	✓		
Reducing HCAIs in England (2009)[23]	✓			✓			
START SMART then FOCUS (2011)[24]	✓	✓		✓	✓	✓	

Nb. The Heath Act (2006) was superseded by The Health and Social Care Act (2008) and Saving Lives (2007) was superseded by Start Smart and then Focus (2011)

These publications have focused on measures or interventions to combat AMR, the spread of infection and also to reinforce good prescribing practice *(see Appendix I)*. These publications and other guidelines on medicines management have been mapped to ASAT v15a *(see table 1.1 and table 1.2 respectively)*.

Table 1.2 - Published guidelines which are targeted at the medicines management in hospitals mapped to ASAT Domains

GUIDELINES/REPORTS/POSITION STATEMENTS (MEDICINES MANAGEMENT)							
Guidelines or reports or position statements	**ASAT DOMAINS**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
A Vision for Pharmacy in the new NHS (2003)[25]							✓
Building a safer NHS for patients (2004)[26]					✓		
Standards for proficiency for nurses and midwives (2006)[27]					✓		

Table 1.2 *(cont'd)* - Published guidelines which are targeted at the medicines management in hospitals mapped to ASAT Domains

GUIDELINES/REPORTS/POSITION STATEMENTS (MEDICINES MANAGEMENT)							
Guidelines or reports or position statements	**ASAT DOMAINS**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Medicines Matters (2006)[28]					✓		
Good Practice in prescribing medicines: Guidance for doctors (2008)[29]					✓		
Standards for Medicines Management: NMC (2010)[30]					✓		
Standards for Conduct, Ethics and Performance (2010)[31]					✓		✓

1.3.1 Antimicrobial stewardship programmes (US perspective)

Position statements which have been produced by the Society for Healthcare Epidemiology of America (SHEA) and Infectious Disease Society of America (IDSA) have also supported this concept of antimicrobial stewardship.[5;6;32] IDSA published guidelines which advocated a multidisciplinary approach to ASPs. These guidelines were the first to recommend a coordinated, multidisciplinary approach to ASPs. They recommended that hospitals should have a dedicated *'antimicrobial agents team'*. This team would have the remit of promoting prudent antimicrobial prescribing within their organisations. The multidisciplinary team would consist of healthcare professionals from clinical microbiology, infection control and pharmacy services and be led by an infectious disease physician.[5;32] Other position statements produced by IDSA in 1997 and 2007 respectively have expanded the concept of antimicrobial stewardship to increase the responsibility of pharmacists. [6;33] Dellit et al (2007) refers to *'antimicrobial agents teams'* as *'antimicrobial stewardship teams*'. They recommend that pharmacists should have specialist training in infection management and should have a central role in coordinating ASPs in hospitals.[5]

1.3.2 Antimicrobial stewardship programmes (European perspective)

In September 1998, an invitational conference 'The Microbial Threat' was held in Copenhagen to discuss the increasing trend of AMR being observed in European states and also to generate recommendations for antimicrobial management.[34] One of the key recommendations made was that hospitals should have dedicated *'antimicrobial teams'*. These teams would have the remit of evaluating antimicrobial prescriptions and monitoring compliance to clinical guidelines.[34] The recommendations state,

'Antimicrobial teams, including clinical microbiologists, infectious disease specialists and other appropriate specialists, should be introduced in every hospital. The teams should also cover nursing homes and other residential institutions and the primary/secondary care interface'.

In 2001, an invitational EU conference which focused on AMR was held.[35] The aim of this conference was to assess progress against the Copenhagen recommendations, specifically examining the following:

- coordinated multidisciplinary actions
- surveillance or registration of resistance to antimicrobials
- monitoring the use of antimicrobials
- implementing prudent use of antimicrobials-from guidelines to practice

In terms of progress against implementing prudent use of antimicrobials, there was progress reported in EU countries. The report indicated that most major hospitals in EU countries had an infection control team which were involved in counselling infectious disease management and antimicrobial usage. However, there was lack of human resources and funding for these activities. Again, the recommendations of this conference suggested a multidisciplinary approach to ASPs, stating that *'Ideally the team should consist of an infectious disease physician and/or a clinical microbiologist, a pharmacist with special expertise in antimicrobial agents and a senior nurse'.*

A number of AMR-related initiatives were developed in response to the findings and recommendations of these conferences. European Surveillance of Antibiotic Consumption (ESAC) project was launched in 2001. This project which was funded by the European Centre for Disease Prevention and Control (ECDC) collects data on the drugs used to treat infections from microorganisms including antimicrobials.

Simultaneously, another project which focused on collecting data on the prevalence of AMR in Europe which was funded by ECDC and European Antimicrobial Resistance Surveillance System (EARSS) is currently ongoing. These aims of these projects are to provide an overview of the emerging trends in antimicrobial consumption in conjunction with AMR across Europe.

The Antibiotic Resistance, Prevention and Control (ARPAC) project was conducted over a three year period which ended in 2005. This project was a European Commission Concerted Action project and was led by the European Society of Clinical Microbiology. The aim of this project was to produce recommendations and strategies for controlling the spread of resistant pathogenic microorganisms in European hospitals.[16] One of the major recommendations from ARPAC was that the role of the pharmacist should evolve in hospitals in order to undertake a more significant and visible role in combating AMR and improving antimicrobial prescribing. The ARPAC recommendations were as follows:

- the development of educational programmes to create more clinical specialists in antimicrobial prescribing
- nationwide education, training and accreditation for antimicrobial pharmacists (AMP) should be promoted
- AMP role should include reviewing antimicrobial orders, design and promotion of clinical guidelines, implementation of switch programmes and documenting the effectiveness of interventions
- AMPs should play an active role in their hospital's Drugs and Therapeutics Committees (D&TCs). These committees should maintain responsibility for antimicrobial policy management and prudent antimicrobial prescribing
- advice from clinical microbiologists or ID physicians and AMPs should be available 24 hours.
- hospital pharmacists should lead on antimicrobial consumption surveillance. These data should be categorised by class and reviewed monthly. The World Health Organisation (WHO) unit of defined daily doses per 100 occupied bed days (DDD/100 bed days) and the Anatomical Therapeutic Chemical (ATC) classification system should be used.
- hospital pharmacists should play an important role in both educational and audit programmes in antimicrobial prescribing

ARPAC also recommended that each EU country should have a national strategy to coordinate AMS-related policies and practice.[36]

In 2006, the Antibiotic Strategies International (ABS) project aimed to implement strategies for appropriate use of antimicrobials in hospitals within member states of the EU. This was the first EU-funded initiative which focused on implementing structural measures in hospitals in order to promote the prudent use of antimicrobials. This initiative recommended hospital-based strategies such as an antimicrobial list, an antimicrobial treatment guide, a surgical prophylaxis guide, tools for antimicrobial consumption analysis and also an antimicrobial-related organisation (antimicrobial officer and management team).[37] ABS International reported that there were several successful initiatives which were developed as a result of their project.[38] An example of a successful initiative was exemplified by the development of national committees by EU member states which aimed to promote infection control and hospital hygiene and subsequently reducing AMR. However, they reported that there were barriers to implementing AMS in hospitals such as staffing levels and education levels of medical specialists such as infectious disease specialists, and clinically trained pharmacists.

1.3.3 Antimicrobial stewardship programmes (UK perspective)

The development of ASPs in the United Kingdom (UK) was conducted in response to the publication guidelines and reports which focused on improving antimicrobial prescribing and also infection prevention and control procedures *(see table 1.1 and table 1.2)*.

The first report examining the measures that hospitals used to control antimicrobial prescribing was published in 1994 by a British Society of Antimicrobial Chemotherapy (BSAC) working party on antimicrobial chemotherapy.[39] They found that approximately 50% of UK hospitals had antimicrobial control measures such as guidelines and formularies in their organisations. However, these control measures were poorly policed, even though pharmacists and clinical microbiologists were highly motivated to improve antimicrobial prescribing in their hospitals.

More recently, two national surveys were conducted in England to investigate the methods used to control antimicrobial usage in hospitals.[39;40] These surveys were conducted approximately 10 years apart from each other. Woodford et al (2004) reported that hospitals had antimicrobial controls such as policies, guidelines and

formularies. However, they concluded that there was not a significant increase in the use of antimicrobial control documents in hospitals. Regional audits of antimicrobial prescribing policies were conducted in 1999 and in 2004 respectively, in the South East of England. These surveys found that was a disparity in the content of the policies and also some policies did not reflect the guidelines.[41] There has been a national survey conducted since the Woodford study, which was conducted in June 2003 and their findings were similar to the Woodford study .[42] Currently, a national survey of ASPs in England is being conducted by Imperial College and the Imperial Healthcare Trust. Although, the results of the survey were due to be published in late 2012, this has not happened as yet.[43]

In the mid-nineties, the issue of AMR *(see section 1.4.4)* was becoming more prominent and therefore the chief medical officer requested that the Standing Medical Advisory Committee (SMAC) examine the issue of AMR in relation to prescribing practice. Also, in 1997 the Select Committee on Science and Technology examined the issue of AMR and provided recommendations on control mechanisms for AMR and the prudent use of antimicrobials in human medicine. They indicated that the presence of antimicrobial controls measures were insufficient interventions to tackle AMR. They recommended that professional education and continual professional development in prudent antimicrobial prescribing was crucial as well. The Specialist Advisory on Antimicrobial Resistance (SACAR) was developed in response to the SMAC report. The main remit of SACAR was to provide expert advice on resistance issues arising from the antimicrobial use including medical and veterinary usage. In 2007, SACAR was subsequently replaced by Advisory Committee on Antimicrobial Resistance and Healthcare Associated Infection (ARHAI). In 1998, SMAC produced a report 'The Path of Least Resistance' which outlined specific measures hospitals should undertake to combat AMR.[13]

They recommended that:

- prescribing guidelines should be quality evidence-based documents
- local prescribing information should, wherever possible, be harmonised with prescribing information in the British National Formulary
- local prescribing guidelines should take their cue from these national guidelines
- all such local guidelines should include, as a minimum, advice on drug, dose, frequency and duration.

The HSC1999/049 circular published in 1999 summarised and reinforced the key findings from both of these reports.[44] In 2000, the UK Antimicrobial Resistance and Action Plan report was published.[45] Although it was a UK based strategy document, it was based on other reports on combating AMR such as The Microbial Threat and the World Health Assembly Resolution of May 1998. The UK Antimicrobial Resistance and Action Plan proposed that there should a multifaceted approach to combating AMR which encompasses surveillance, prudent antimicrobial use and also infection control. This approach was described in the action areas of the strategy and also highlights that public role's in reducing AMR. The Clinical Prescribing Sub-group (CPSG) of the Interdepartmental Steering Group on Antimicrobial Resistance was established to oversee the implementation of the UK Antimicrobial Resistance and Action Plan. The CPSG proposed that there was an important role for clinical microbiologists in reducing AMR. The report stated, *'A consultant microbiologist post was proposed, to visit, liaise with, teach and otherwise influence the practice of all the prescribers in a city-wide area. This would be done in association with pharmacy leads, and be supported by a clinical scientist post. The appointed person would be responsible for city-wide surveillance and local education and health promotion for the population*'.

In 2002, Getting Ahead of the Curve which was a strategy for combating infectious diseases was published. [46] The aim of this publication was to prioritise actions for combating infectious diseases and also highlight some of the future threats from infectious diseases. One of the key recommendations from the strategy was the proposal of a *'strengthened and integrated system of infectious disease and health protection surveillance'*. Implementation of this recommendation would include the creation of '*a single point for co-ordination, analysis and reporting on all the different systems of infectious disease surveillance'.* This surveillance system would incorporate data from other relevant sources as antimicrobial prescribing patterns.

In 2003, the Hospital Pharmacy Initiative (HPI) was developed in response to Getting Ahead of the Curve.[47] The aim of the HPI was to provide funding to hospitals *'for promoting prudent antibiotic prescribing through enhanced clinical pharmacy activity'*. £12 million over a 3-year period was made available to NHS hospitals trusts to fund this initiative.[47] It was proposed that this funding should result in the expansion of clinical pharmacy services to include AMS. The key areas of focus were surgical prophylaxis, antimicrobial use in children and also infection control.

The Chief Medical Officer published Winning Ways[13], which aimed to set out a clear, local direction for NHS hospitals to combat AMR and also reduce HCAIs. This report consisted of seven action plans which included recommendations for tackling the spread of infection and AMR. Action area five focused a prudent antimicrobial prescribing and recommended a multidisciplinary approach to antimicrobial prescribing. The report recommended, '*support for prudent antibiotic prescribing in hospitals will be provided by the clinical pharmacists, medical microbiologists and infectious diseases physicians on the staff*'.

More recently, the Health and Social Care Act published in 2008[21] reinforced the message of prudent antimicrobial prescribing. Criterion 9 which focuses on healthcare organisations having and adhering to policies and which have been tailored for local requirements. These policies should help to prevent and control the spread of infections. In terms of antimicrobial prescribing, The Act recommends the following:

- *local prescribing should, where appropriate, be harmonised with that in the British National Formulary. Local guidelines for primary and secondary care should be observed*
- *all local guidelines should include information on a particular drug's regimen and duration*
- *procedures should be in place to ensure prudent prescribing and antimicrobial stewardship. There should be an ongoing programme of audit, revision and update. In healthcare, this is usually monitored by the antimicrobial management team*

The Act also provides specific recommendations for the management of Meticillin-resistant *Staphylococcus aureus* (MRSA), *Clostridium difficile*, Glycopeptide-resistant *Enterococci* (GRE), *Acinetobacter spp.* and other resistant organisms. Detailed recommendations for the management for *Clostridium difficile* have been outlined in *Clostridium difficile:* How to Manage the Problem.[22]

In 2011, Antimicrobial stewardship: Start Smart - then Focus[24] was published by ARHAI, which superseded Saving Lives which was published in 2007. The aim of this publication is to provide NHS hospitals with an outline for evidence-based AMS. This report is accompanied with a suite of resource tools so that hospitals can routinely audit their prescribing behaviour. These guidelines have been categorised into two sections and there are as follows:

START SMART:

- do not start antibiotics in the absence of clinical evidence of bacterial infection
- if there is evidence/suspicion of bacterial infection, use local guidelines to initiate prompt effective antibiotic treatment
- document on drug chart and in medical notes: clinical indication, duration or review date, route and dose
- obtain cultures first
- prescribe single dose antibiotics for surgical prophylaxis; where antibiotics have been shown to be effective

THEN FOCUS:

- review the clinical diagnosis and the continuing need for antibiotics by 48 hours and make a clear plan of action **-** the '*Antimicrobial Prescribing Decision'*
- the five Antimicrobial Prescribing Decision options are: Stop, Switch IV to Oral, Change, Continue and Outpatient Parenteral Antibiotic Therapy (OPAT).
- it is essential that the review and subsequent decision is clearly documented in the medical notes**.**

These guidelines focus primarily on the prescribing decision and not strategies for implementing antimicrobial stewardship in hospitals. Also, the National Institute for Health and Clinical Excellence (NICE) in conjunction with the Health Protection Agency (HPA) have produced a quality improvement guide for the prevention and control of HCAIs.[48] This guide is not mandatory for hospitals however it is suggested that it is used as quality standards for tacking HCAIs. The guide consists of 11 quality improvement statements which could be used for auditing purposes. These statements focus on processes such as the role of the Trust Board and the role of surveillance mechanisms for HCAIs.

There were four models for implementing ASPs in UK hospitals described in the literature. The West London model was described by Cooke and her colleagues who endeavoured to implement an ASP in Hammersmith Hospitals NHS Trust, which was a 1000-bed split site facility.[49] They identified seven key elements to the success of implementing their programme and improving antimicrobial stewardship. The elements were strong leadership (for example by the medical director);

dedicated individuals with the responsibility for leading on antimicrobial use, integration into pre-existing structures within the trust, harnessing existing resources to deliver change, obtaining local data on prescribing and resistance patterns, communication and also education and training. However, they noted that one of the major barriers to implementing ASPs was the service commitment of all staff including clinical microbiology and infectious disease pharmacists. Another barrier highlighted was gaining acceptance of ASPs in specialist groups and they suggested that this could be overcome by the appointment of link consultants in each speciality. The ASP model used in Manchester was reported by Williams and his colleagues. The implementation of this ASP was conducted at a two hospital site with a 900-bed capacity.[50] They undertook an approach that consisted of three main elements which included education and training. The ASP was jointly led by pharmacy and clinical microbiology and coincided with the formation of an antimicrobial sub-committee. This sub-committee was supported by the Trust's medicines management committee. Innovative ideas to promote and disseminate antimicrobial guidelines such as;

- pocket version of guidelines for prescribers
- hospital intranet version on all trust computers
- Personalised Digital Assistant (PDA)/pocket PC version and
- a summary of guidelines printed on a sticker placed on the back of the British National Formulary and also on mouse mats

They reported that the main achievements were the reduction of patients on IV antimicrobials for longer than 48 hours and also the number of patients on inappropriate IV antimicrobials. Also, they reported that the cost savings associated with the ASP was approximately £350 000. In Ipswich, Cheeseman and his colleagues reported on an ASP initiative within their trust.[51] This initiative was conducted at Ipswich Hospital NHS Trust, which is an 800-bed district general hospital (DGH). They implemented a joint review of patients on antimicrobials by pharmacists and clinical microbiologists. The prescriptions were reviewed using the following criteria;

- inappropriate choice of antimicrobial for infection being treated
- inappropriate duration of antimicrobial
- inappropriate route of antimicrobial treatment
- inappropriate dosage

The most common prescribing error was inappropriate choice of antimicrobials. One of the limitations identified in the Ipswich experience was the inability to identify why patients had been prescribed an antimicrobial. They found that the indication was not recorded in all cases and resolving this issue was time-consuming and resource intensive. The benefits of the ASP were that pharmacists felt more empowered to challenge inappropriate prescribing and also there was greater collaboration between pharmacy and microbiology. A similar ASP was set up in Southampton and the initial trial period was conducted over a 3-month period.[52] This ASP was developed mainly around the collaboration between pharmacists and clinical microbiology. They reported that the ASP resulted in cost savings however there was limited description of the benefits of the ASP.

1.4 Rationale for antimicrobial stewardship programmes

There are numerous reasons for promoting prudent antimicrobial prescribing via ASPs in hospitals, which are discussed in *section 1.4.1* to *section 1.4.4*.

1.4.1 Inappropriate prescribing

Firstly, it has been estimated that approximately 50% of antimicrobials are prescribed inappropriately in hospitals.[53-55] Studies have shown the relationship between inappropriate antimicrobial usage and the development of CDI.[56-58] Dryden et al (2011) provides a list of common examples of inappropriate prescribing of antimicrobials such as prescribing antimicrobials unnecessarily, delayed administration for critically-ill patients and also prescribing antimicrobial therapy with an inappropriate spectrum of activity.[59] Other reasons highlighted in the literature included the paucity of novel antimicrobial agents currently being developed, AMR, patient safety and costs associated with antimicrobial overconsumption when treating patients with infections.[60;61]

1.4.2 *Clostridium difficile* infection (CDI)

The incidence of *Clostridium difficile* infection (CDI) has been linked to the use of penicillins, cephalosporins and fluoroquinolones.[61-66] More recently, the increasing emergence of hyper-virulent strain of *C.difficile* has been reported in Europe and the US.[62;67] This strain of *C.difficile* has been linked to the use of quinolones.[62;68]

In the UK, there has been a reduction in the number of CDI reports received by the HPA *(see table 1.3).* The number of deaths from CDI has decreased by 31% from 2009 to 2010 i.e. from 3,933 to 2,704. From between 2006 to 2010, *C.difficile* was involved in less than 2% of hospital deaths.[69]

Table 1.3 - Trust apportioned counts and rates of CDI by financial year (April 2007 to March 2011) for NHS trusts in England

Financial Year	CDI reports	CDI rates per 100 000 bed days
April 2007 - March 2008	33,442	93.3
April 2008 – March 2009	19,927	54.9
April 2009 – March 2010	13,221	36.7
April 2010 – March 2011	10,414	28.9

Source: http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1278944283388

1.4.3 Development of new antimicrobials

During the 1940s to 1970s, there was steady stream of new antimicrobials were being produced by the pharmaceutical industry *(see figure 1.1)*. Many of these agents had new mechanisms of action which enabled these drugs to combat bacterial resistance. However, the rate of production of new antimicrobial agents has decreased since the 1970s and the pharmaceutical industry has downgraded the development of novel antimicrobial agents.[63]

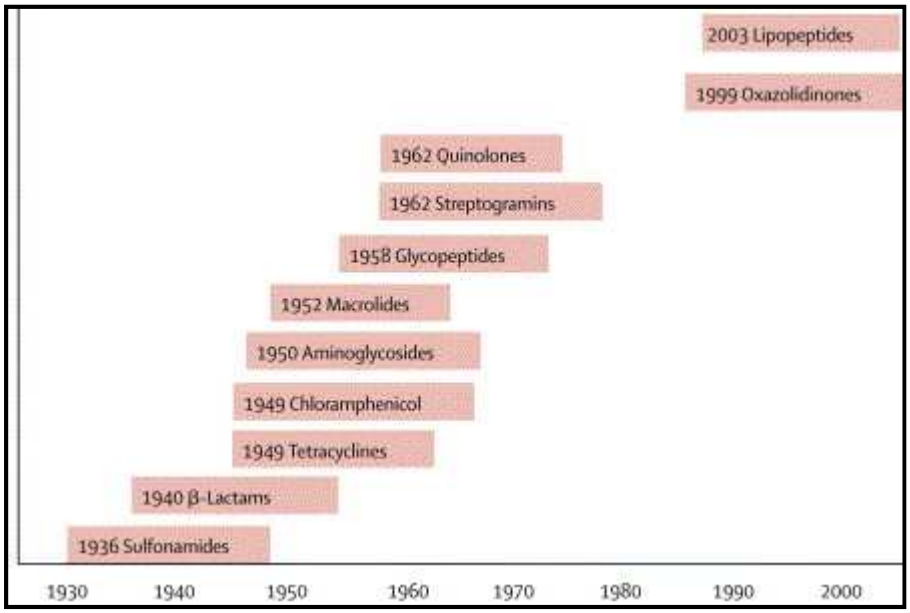

Figure 1.1 - The development of new antimicrobials from 1930s to 2000s[70]

In order to combat AMR *(see section 1.4.4)*, the development of new antimicrobials is essential to manage infections. Organisations with the remit of infection prevention and control have produced a number of reports highlighting the need for the development of new antimicrobials.[71;72] Due to the prevalence and socio-economic burden of HCAIs and AMR, there have been international and national initiatives to address the utilisation of antimicrobials in both secondary care and tertiary care settings. The '10x20' initiative has been developed to combat the lack of new antimicrobials being currently developed.[73] Reports produced by the infectious Disease Society of America (IDSA) '*Bad Bugs, No Drugs: no ESKAPE! an update from the IDSA*'[74] and the European Medicines Agency '*The Bacterial Challenge: time to react'*[75], both indicate that there are few candidate drugs which have a higher efficacy than current drugs that could be used to treat infections due to 'ESKAPE' pathogens. The ESKAPE pathogens are ***E****nterococcus faecium,* ***S****taphylococcus aureus,* ***K****lebsiella pneumonia,* ***A****cinobacter baumanii,* ***P****seudomonas aeruginosa and* ***E****nterobacter species*. More recently, reports such as TATFAR (2011) have indicated that there is a need to address the problem of new antimicrobial development.[76]

1.4.4 Antimicrobial resistance

AMR has been identified by WHO as one of the greatest threats to human health.[75;76] The development of AMR by pathogens is a major hindrance to antimicrobial chemotherapy in hospitals because many resistant pathogens are responsible for HCAIs such as Meticillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *enterococci* (VRE). AMR reduces the efficacy of antimicrobial drugs ineffective against invading pathogens. Exposure to AMR organisms can have negative impacts on hospitalised patients and the local hospital ecology.[77] Both inappropriate prescribing and overprescribing of antimicrobials have been linked to the development of AMR.[78] Selection pressure for resistant organisms in hospitals is higher than in other healthcare facilities.[65] In other words, antimicrobials will kill susceptible bacteria and resistant bacteria will survive and replicate. Selection pressure, in conjunction with sub-standard infection prevention and control practices can explain the high prevalence of AMR in hospitals.[65;77] Monitoring antimicrobial consumption in hospitals is therefore necessary in order to gain a better understanding of AMR prevalence data.[65]

AMR is a major concern to healthcare providers because of the prevalence and emergence of multi-drug resistance and also pan-drug resistance.[79] Carbapenems such as meropenem, ertapenem and imipenem are effective against multi-resistant gram negative bacteria especially those bacteria with extended spectrum beta-lactamases (ESBLs). However, plasmid-mediated CTX-M EBSLs have become increasingly prevalent in European countries[80] and the US.[81] The emergence of carbapenamases such as *Klebsiella pneumoniae* should be a main concern of healthcare providers because AMR restricts the antimicrobial therapeutic options available to treat these infections.[79;82] These resistant pathogens are becoming more of a concern especially in critical care or intensive therapy wards.[83] Also, routine antimicrobial susceptibility testing may not identify *Klebsiella pneumoniae* carbapenenmase (KPC) producing bacteria because these organisms are difficult to karyotype.[79]

In January 2009, a National Resistance Alert was issued in response to an increasing number of carbapenem-resistant strains of *Enterobacteriaceae* being identified in hospitalised patients in the UK. This alert indicated that the production of metallo-*β*-lactamase, New Delhi Metallo-1 (NDM-1) was becoming more prevalent in the UK. Examples of the NDM-1 producing bacteria that were being reported were *Escherichia coli (E.coli), Citrobacter freundii, Enterobacter cloacae* and *Morganella morganii.* The HPA reports on the mandatory surveillance of bacteria in the UK and recently reported that the incidence of *E.coli* reports have increased from 19,993 in 2006 to 27,005 in 2010 *(see figure 1.2)*.

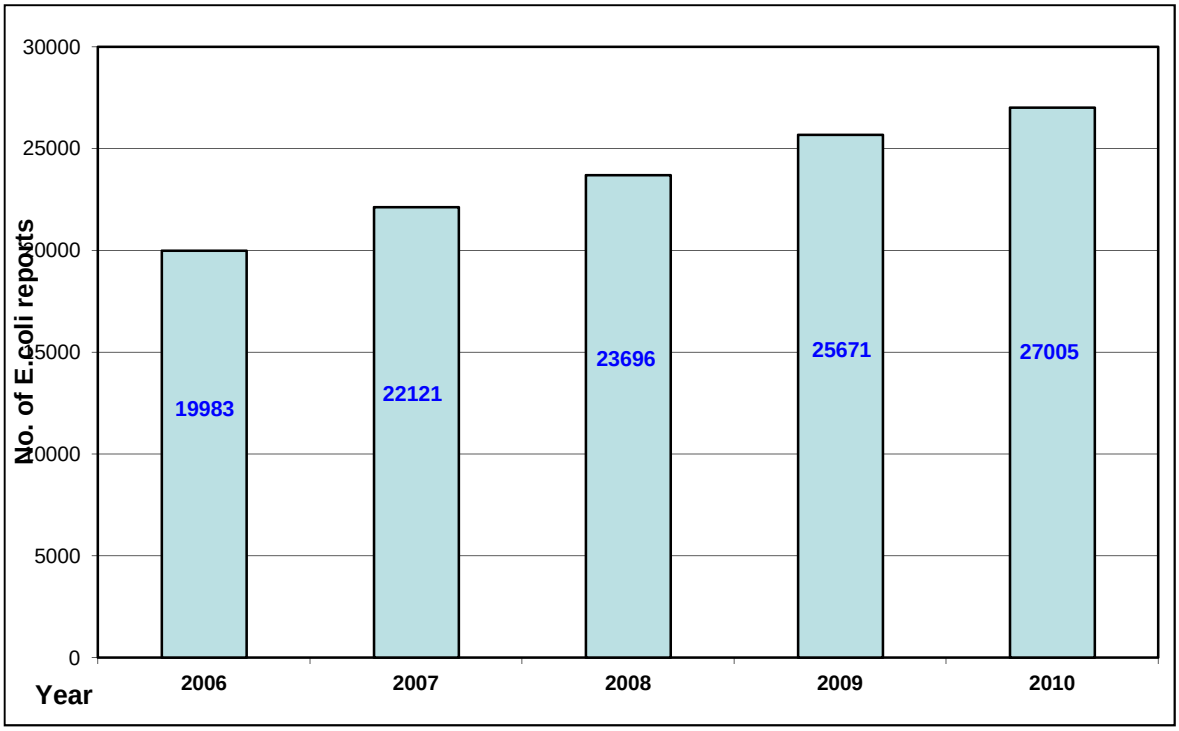

Figure 1.2 - *E. coli* bacteraemia reports for England, Wales and Northern Ireland: 2006 to 2010*
Source: http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1296686942137
Escherichia coli bacteraemia in England, Wales and Northern Ireland, 2006-2010

NDM-1 was first described in the UK in 2009.[84] The increasing prevalence of NDM-1 means that potentially it can become a global threat so therefore a co-ordinated international surveillance approach is required.[82]
More recently, phenotypic and genotypic studies were conducted to characterise *Neisseria gonorrhoeae (N. gonorrhoeae*) strain (H041) which is usually treated with ceftriaxone. This study demonstrated that *N. gonorrhoeae* was able to develop ceftriaxone resistance, indicating that it may potentially become an untreatable organism.[85]

It has been estimated that HCAIs such as MRSA, Meticillin-sensitive *Staphylococcus aureus* (MSSA), Vancomycin-resistant *Enterococci* (VRE) and *E.coli* bacteraemias, cost the NHS approximately £1 billion per year.[86] The latest figures produced by the HPA for MRSA are shown in Table 1.4. The number of deaths from MRSA has decreased by 38% from 2009 to 2010, that is, from 781 to 485. From between 2006 and 2010 MRSA was implicated in 0.4% of hospital deaths.[87]

Table 1.4 -Trust apportioned counts and rates of MRSA bacteraemia by financial year (April 2008 to March 2011) in NHS trusts in England

Financial Year	MRSA bacteraemia reports	MRSA bacteraemia rate per 100 000 bed days
April 2008 – March 2009	1,606	4.3
April 2009 – March 2010	1,004	2.7
April 2010 – March 2011	689	1.8

Source: http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1278944283762 *Nb. There was a 31% reduction in the number of MRSA bacteraemias reported in 2010/11 for 2009/10*.

Reducing the rates and prevalence of AMR and the promotion of prudent antimicrobial prescribing has been the subject of published guidelines, reports and also position statements as previously discussed *(see section 1.3)*. These publications recommend interventions for tackling the issue of AMR and poor antimicrobial prescribing. The next section of this chapter describes the findings from the review of current available evidence on ASPs. In this current literature review, the results are reported based on the methods used for implementing ASPs. Implementing interventions involves strategies used to promote evidence-based practices and research findings into routine clinical practice. These interventions are aimed to improve the quality of health care in terms of effectiveness, reliability, safety, appropriateness, equity and efficiency.[88] As previously discussed, the purpose of the ASAT *(see section 1.5)* is to evaluate whether hospitals possess the necessary organisational methods of implementation for effective ASPs. These methods are primarily strategic and operational and are targeted at the members of staff who are involved in the antimicrobial prescribing pathway and also incorporates infection management policies. The ASAT does not measure or quantify actual antimicrobial prescribing such as antimicrobial consumption. In November 2011, 'START SMART and then FOCUS'[24] was published. This publication provides standards for antimicrobial prescribing and a suite of tools to audit antimicrobial prescribing. The ASAT *(see section 1.5)* has been signposted by this publication as one of the resources that hospitals can use to evaluate or audit their organisational implementation methods for ASPs.[89]

1.5 Antimicrobial Self-Assessment Toolkit (ASAT v15a)

The Antimicrobial Self-assessment Toolkit (ASAT v15a) *(see Appendix XXVIII)* was developed by a pharmacist reference group of an Advisory Non-Departmental Public Body on Antimicrobial Resistance and Healthcare Associated Infections (ARHAI), in conjunction with the Department of Health (DH). This version of the ASAT can be accessed via http://www.researchdirectorate.org.uk/uhsm/asat/asat.asp. The ASAT is an evidence-based toolkit which contains organisational methods of implementing hospital-based ASPs *(see table 1.5)*. The primary purpose of the ASAT is to identify and to assess the organisational methods of implementation utilised by NHS Trusts to promote AMS within their respective organisations. It embodies the relevant guidelines produced relating to AMS and also published research studies translating them into a single workable document.[90] Consensus expert opinion from the members of ARHAI which was based experiential knowledge in antimicrobial management and prescribing was used to inform some of the content of the toolkit.

Table 1.5 - Headings and Descriptions of the Domains of ASAT v.15a

DOMAIN	MAIN HEADING	DESCRIPTION
1	Antimicrobial management with the Trust	Examines the Trust Board roles in ensuring good antimicrobial management
2	Operational delivery of antimicrobial strategy	Examines the types of control documents such as antimicrobial guidelines
3	Risk assessment for antimicrobial chemotherapy	Examines patient safety principles that should be undertaken when prescribing antimicrobials
4	Clinical governance assurance	Examines compliance to clinical guidelines and policies by clinical audits
5	Education and Training	Examines the education, training needs and training packages available to antimicrobial prescribers
6	Antimicrobial Pharmacist	Examines the role of the antimicrobial pharmacist to optimise their role in antimicrobial stewardship
7	Patients, Carers and the Public	Information given to the public such as consent for antimicrobial therapy

As previously discussed, the quality of antimicrobial prescribing or the appropriateness of prescribing decisions in terms of route of administration, dose, frequency or duration of antimicrobial therapy by antimicrobial prescribers in NHS trusts is not evaluated or audited by the ASAT. The publication 'START SMART and the FOCUS'[23] includes a suite of tools which could be used to evaluate or audit

antimicrobial prescribing. Some examples of these tools include the Hospital Antimicrobial Prudent Prescribing Indicators (HAPPI) audit tool and the Antibiotic Review Bundle.[91] The ASAT evaluates implementation strategies from an organisational perspective. In other words, it aims to examine the strategic approaches that NHS Trusts utilise in order to ensure that there are systems embedded within their organisations to assist, equip and educate antimicrobial prescribers to prescribe prudently.

Prior to commencing this programme of work, an analysis and critique of the evidence base underpinning organisational implementation strategies for implementing ASPs *(see section 1.6 to section 1.19)* was conducted. This literature review was done to ensure that the ASAT v15a incorporated and assessed the relevant interventions for implementing effective ASPs in hospitals.

1.6 RESEARCH QUESTIONS FOR LITERATURE REVIEW

- What are the organisational methods of implementation of ASPs in hospitals?
- Does ASAT v15a include and measure the organisational interventions required for the implementing effective ASPs in hospitals?

1.7 AIMS

- To review the evidence base to date that underpins the organisational interventions used to implement effective ASPs in hospitals

1.8 OBJECTIVES

- To search relevant databases in order to identify research articles that focus on implementation strategies for effective antimicrobial stewardship programmes in hospitals
- To critically appraise the research articles identified using reporting guidelines such as PRISMA, TREND and ORION[92], where appropriate
- To summarise and synthesise the findings of the literature review and to use these findings to justify the contents of the ASAT

1.9 METHODS

Search strategy

A systematic search was conducted via OVID online which provided access to a range of databases that contain articles on research in healthcare. These databases and a brief description of the types of articles they contain are listed below:

EMBASE (1980 to present): this is a major biomedical and pharmaceutical database indexing over 3,500 international journals in fields such as drug research, health policy and management and public health.

OVID MEDLINE (1946 to present): this database covers international literature on biomedicine and other specialities as they relate to medicine and healthcare, indexing approximately 5,400 journals internationally.

EBM REVIEWS (1991 to present): this database is made up of seven Evidence Based Medicine Reviews databases such as Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, Health Technology Assessment and NHS Economic Evaluation

INTERNATIONAL PHARMACEUTICAL ABSTRACTS (1970 to present): this database provides comprehensive information on drug therapy, toxicity and pharmacy practice as well utilisation, education and economics as they relate to pharmaceutical science and practice.

Other data sources were searched in order to ensure that the most relevant articles are retrieved such as NHS Evidence.

HEALTH AND PSYCHOSOCIAL INSTRUMENTS - HAPI (1985 to present) this database provides comprehensive information on measurement instruments for example questionnaires, interview schedules, checklists and rating scales) in fields such as health fields and organisational behaviour.

NHS EVIDENCE enables access to authoritative clinical and non-clinical evidence and best practice. It helps people from across the NHS, public health and social care sectors to make better decisions as a result. NHS Evidence is managed by the National Institute for Health and Clinical Excellence (NICE).

Date range

December 1988 to present

The first published guidelines on improving the use of antimicrobials was published by IDSA and SHEA in 1988, therefore studies conducted after 1988 were included in this literature review.

Primary search terms:

Table 1.6 - The search terms used (PICO format) [93] in literature review on ASPs

Patient or Population or Problem - any characteristics that define your patient or population, e.g. target clinical condition, co-existing condition, ethnicity, age group	**Intervention –** what you want to do with the patient or population or problem(s) e.g. form of treatment, diagnostic test, education programme, type of service delivery.	**Outcome or Effects** What are you trying to accomplish measure, improve or affect?
inpatients, hospitalised patients, secondary care, acute care, tertiary care AND infections OR sepsis	antibiotic(s), antimicrobial(s), antibacterial(s), anti-infective(s) AND prudent, rational, optimal prescribing stewardship programmes, stewardship committee or team, management, infection management policy, guideline(s), treatment or therapeutic guidelines, surgical prophylaxis guidelines clinical indication, choice, route, dose, duration, iv to oral switch, parenteral to oral, empirical broad spectrum to narrow spectrum, de-escalation therapeutic drug monitoring, ward round formulary restriction, joint formulary antibiotic or antimicrobial resistance surveillance audit, governance, point prevalence,	length of stay re-admissions death antibiotic or antimicrobial resistance hospital or healthcare acquired or associated infections clinical improvement cost policy or guideline compliance (indication, antimicrobial choice, duration, route, frequency, timing of first dose, redosing) antimicrobial consumption

Patient or Population or Problem - any characteristics that define your patient or population, e.g. target clinical condition, co-existing condition, ethnicity, age group	**Intervention –** what you want to do with the patient or population or problem(s) e.g. form of treatment, diagnostic test, education programme, type of service delivery.	**Outcome or Effects** What are you trying to accomplish measure, improve or affect?
	feedback, education, prescribers, dispensers, drug administration ward or clinical or specialist pharmacist, infectious disease physicians or clinicians, nurses, clinical microbiologists medicine adherence	

These search terms were used separately or in combination to retrieve the potentially most relevant articles. The article retrieval process of the literature search is described in *section 1.10.1*. National and international guidelines, position statements and recommendations were identified from the Department of Health (www.dh.gov.uk), National Resource for Infection Control (www.nirc.org.uk), British Society of Antimicrobial Chemotherapy (www.bsac.org.uk), National Institute for Health and Clinical Excellence (www.nice.org.uk), British Thoracic Society (www.brit-thoracic.org.uk/), Surviving Sepsis (www.survivingsepsis.org), Health Protection Scotland (www.hps.scot.nhs.uk), Public Health Wales (www.wales.nhs.uk), European Society for Infectious Diseases and Clinical Microbiology (www.escmid.org), Centres for Disease Control and Prevention (www.cdc.gov), Society for Healthcare Epidemiology of America (SHEA) (www.shea-online.org) and Infectious Diseases Society of America (IDSA) (www.idsociety.org).
Additional papers were selected from the bibliographies of included studies and also by hand searching using the Cochrane Library.

Inclusion criteria

- Full-text papers that were published in peer-reviewed journals. Papers that were not available in full-text were discarded
- Studies that involved interventions relating to antimicrobial stewardship or optimisation in clinical practice
- Studies involving interventions targeting hospital in-patients
- Studies published in English

Exclusion criteria

- Papers which only had abstracts available
- Studies that did not report on antimicrobial stewardship interventions
- Studies that reported on antimicrobial stewardship interventions in out-patient or ambulatory care and community settings
- Studies reporting on veterinary practice, animal husbandry and horticultural antimicrobial use
- Studies not published in English

1.10 RESULTS

1.10.1 Search results (Studies retrieved and included)

The literature review for this programme of work was conducted using OVID online and other additional resources such as NHS Evidence as previous described in section 1.9. It was conducted firstly in 2009 and subsequently updated in 2012 to ensure that the evidence base was current. The process of selecting the 69 included articles is shown in *figure 1.3*.

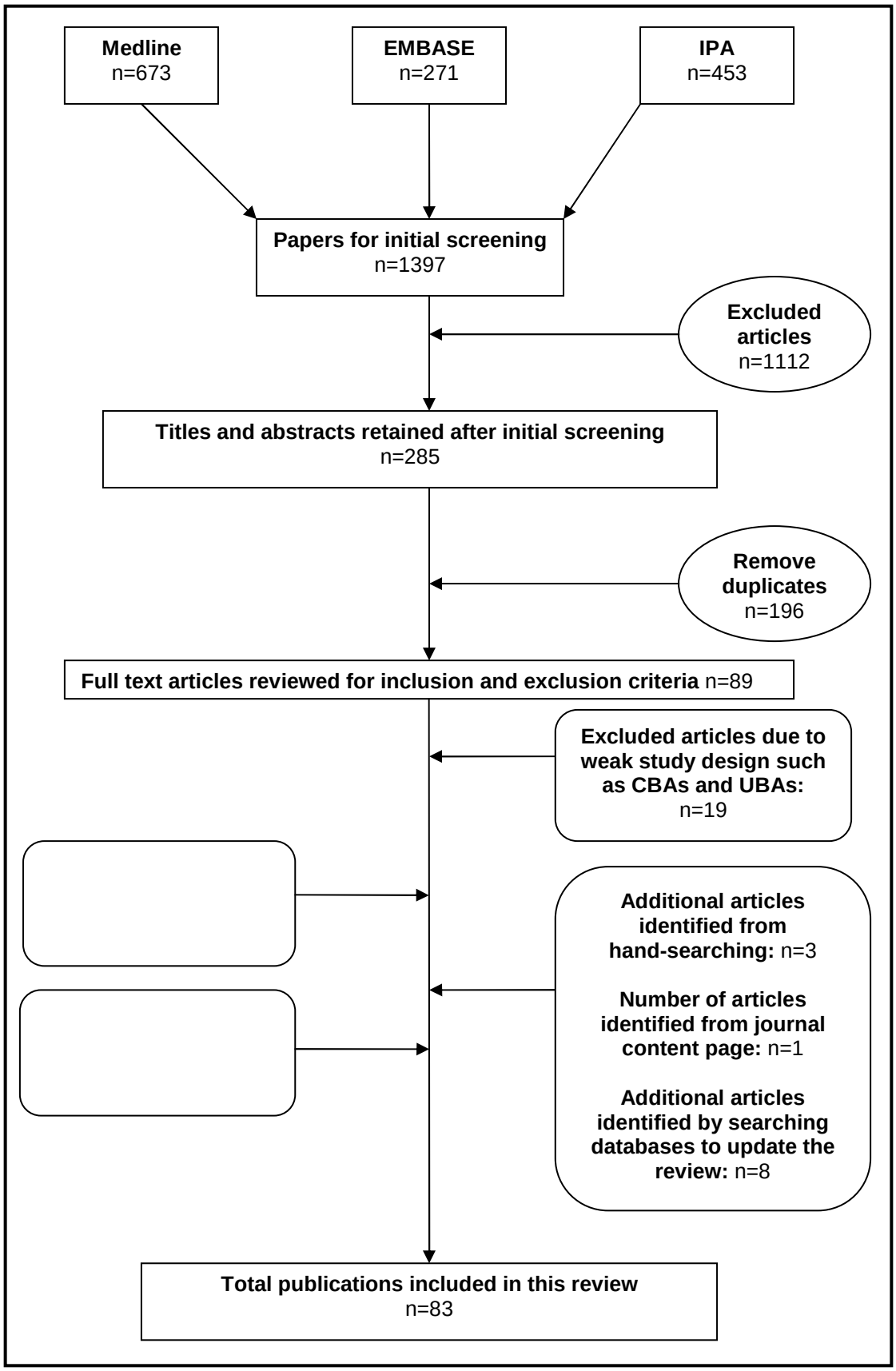

Figure 1.3 - The flow chart of study extraction and selection used in the literature review on organisational methods for implementing hospital-based ASPs

The initial search was conducted across five databases and retrieved 2489 articles. The articles and available abstracts were screened and 1093 articles were excluded because they did not meet the inclusion criteria for the literature review. The remaining 284 articles were further screened in order to ensure that there were no duplicates across the databases.

This literature search was conducted in two stages. Firstly, the initial search was conducted across five databases *(see section 1.9)* and it was found that EBM reviews and HAPI did not retrieve any suitable articles. Therefore, articles were sourced from Medline, EMBASE and IPA and 1397 articles were retrieved. These articles and available abstracts were screened and 1112 articles were excluded because they did not meet the inclusion criteria for the literature review. The remaining 285 articles were further screened and 196 duplicates were removed. Therefore, 89 full text articles were reviewed for inclusion and exclusion criteria. Consequently, a total of 19 articles were excluded from the evidence base due to their focus on determining the optimising the prescribing pathway or due to their weak study designs such as controlled before and after studies (CBAs) and uncontrolled before and after studies (UBAs). On analysis of the 70 remaining articles, it was found that 52 studies which met the inclusion criteria were also included in a Cochrane review. The 15 articles were not included in the Cochrane review because there were conducted after the December 2003.

Secondly, there were 12 articles identified from hand-searching the references of the included studies (n=3), from the content pages of journals (n=1) and also from searching databases in order to update the literature review. This update of the literature search was conducted in June 2012. As a result, 83 studies fulfilled the inclusion criteria for this current literature review *(see Appendix II)*.

In addition to the checklists which were used to evaluate the quality of evidence such as PRISMA and CONSORT[91], the GRADE system for evaluating intervention studies was used to determine the quality and strength of evidence of the included studies.[94] The levels of evidence are described in *table 1.7 (see below)*.

Table 1.7 - GRADE levels of evidence for intervention studies[94]

Level of evidence	Description of evidence
1^{++}	High quality meta-analysis, systematic reviews of RCTs, or RCTs with a very low risk of bias
1^{+}	Well-conducted meta-analysis, systematic reviews of RCTs, or RCTs with a low risk of bias
1^{-}	Meta-analysis, systematic reviews of RCTs, or RCTs with a high risk of bias
2^{++}	High quality systematic reviews of case-control or cohort studies High quality case-control or cohort studies with a very low risk of confounding, bias or chance and a high probability that the relationship is causal
2^{+}	Well-conducted case-control or cohort studies with a low risk of confounding, bias or chance and a moderate probability that the relationship is causal
2^{-}	Case-control or cohort studies with a high risk of confounding, bias or chance and a significant probability that the relationship is not causal
3	Non-analytical studies (for example, case reports, case series)
4	Expert opinion, formal consensus

Each included study was scored according to the definitions provided by the GRADE system to reflect the evidence base of ASAT v15a (*see Appendix II*). This scoring was conducted so that end-users of the ASAT will understand the level of evidence underpinning the ASAT domains.

Based on the GRADE system[93] *(see table 1.7)*, the 83 studies included in this current literature review which were categorised according to their strength of evidence (*see table 1.8)*. 31 studies were RCTs and it was found that four studies scored (1^{+}), 17 studies scored ($1^{+}/1^{-}$) and 10 studies scored (1^{-}). Four studies were CCTs and it was found one study scored (1^{+}), two studies scored ($1^{+}/1^{-}$) and one study scored (1^{-}). 48 studies were ITS and it was found that seven scored (2^{+}), 39 studies were categorised as ($2^{+}/2^{-}$) and three studies were scored as (2^{-}). The categorisation of studies indicated that the majority of studies had a medium risk of bias which meant that there was moderate possibility that the relationship between outcomes and interventions were not causal.

Table 1.8 - Categorisation of the studies included examining organisational implementation of ASPs according to the GRADE level of evidence (LOE) system [93]

GRADE LOE	RCT	CCT	ITS
1^{++}	**-**	**-**	**-**
1^{+}	**Gums (1999)[135]** **Kritchevsky (2008)[140]** **Wyatt (1998)[158]** **Zanetti (2003)[163]**	**de Man (2000)[119]**	**-**
1^{+}/1^{-}	**Bailey (1997)[132]** **Bevilacqua (2011)[127]** **Burton (1991)[181]** **Christi-Crain (2004)[184]** **Christi-Crain (2006)[185]** **Camins (2009)[139]** **Dranitaris (2001)[133]** **Franz (2004)[186]** **Masia (2008)[141]** **Micek (2004)[129]** **Naughton (2001)[154]** **Paul (2006)[183]** **Schouten (2007)[155]** **Senn (2004)[161]** **Shojania (1998)[162]** **Singh (2000)[131]** **Solomon (2001)[156]**	**Doern (1994)[177]** **Tolztis (2002)[125]**	**-**
1^{-}	**Borer (2004)[142]** **Bouza (2004)[143]** **Bruins (2005)[179]** **Destache (1990)[182*]** **Fine (2003)[144]** **Fraser (1997)[134]** **Foy (2004)[169]** **Oosterkeert (2005)[180]** **Trenholme (1989)[178]** **Tsiata (2001)[104*]**	**Pastel (1992)[137]**	**-**
2^{++}	**-**	**-**	**-**
2^{+}	**-**	**-**	**Ansari (2003)[175]** **Carling (2003)[136]** **Everitt (1990)[151]** **Hulgan (2004)[164]** **Kumana (2001)[176]** **Perez (2003)[128]** **Skaer (1993)[148]**
2^{+}/2^{-}	**-**	**-**	**Adachi (1997)[165]** **Arnold (2006)[145]** **Avorn (1988)[149]** **Belliveau (1996)[126]** **Berild (2002)[166]** **Bradley (1999)[116]** **Buising (2008)[150]** **Calil (2001)[117]** **Charbonneau (2006)[115]**

*Nb. Studies were categorised as either (1^{+}/1^{-}) or (2^{+}/2^{-}) where applicable because there were was no discrete classification for studies with a medium risk of bias in the GRADE system. Studies with a very high risk of bias was denoted an asterisk**

Table 1.8 *(cont'd)* - Categorisation of the studies included examining organisational implementation of ASPs according to the GRADE system [93]

GRADE LOE	RCT	CCT	ITS
$2^{+}/2^{-}$	**-**	**-**	**Climo (1998)[105]** **Dempsey (1995)[167]** **Elligsen (2012)[146]** **Fowler (2007)[147]** **Halm (2004)[170]** **Hess (1990)[152]** **Himmelberg (1991)[120]** **Khan (2003)[121]** **Landman (1999)[106]** **Lautenbach (2003)[107]** **McElnay (1995)[108]** **McNulty (1997)[122]** **Mercer (1999)[109]** **Meyer (1993)[110]** **Meyer (2007)[171]** **Mol (2005)[172]** **Patel (1989)[160]** **Pear (1994)[111]** **Richards (2003)[112]** **Saizy-Calleart (2003)[113]** **Salama (1996)[130]** **Sirinavin (1998)[123]** **Stevenson (1988)[168]** **Suwangool (1991)[114]** **Talpaert (2011)[173]** **Toltzis (1998)[124]** **van Kasteran (2005)[159]** **Willemsen (2010)[174]** **Wilson (1991)[157]**
2^{-}	**-**	**-**	**de Champs (1994)[118]** **Lee (1995)[153]** **Richardson (2000)[138]**
3	**-**	**-**	**-**
4	**-**	**-**	**-**

*Nb. Studies were categorised as either ($1^{+}/1^{-}$) or ($2^{+}/2^{-}$) where applicable because there were was no discrete classification for studies with a medium risk of bias in the GRADE system. Studies with a very high risk of bias was denoted an asterisk**

1.10.2 Interventions for changing professional behaviour including general prescribing

Interventions to change healthcare professional practice have been subject of systematic reviews conducted by Cochrane Effective Practice and Organisation of Care Review Group (EPOC). This group have proposed that these interventions should be categorised as professional, financial, organisational, patient-oriented, and structural interventions.[95] A brief summary of these EPOC interventions is given below *(see table 1.9)*.

Table 1.9: EPOC classifications of interventions to change professional behaviour[95]

Intervention	Definition
Professional interventions	
Distribution of educational materials	Distribution of published or printed recommendations for clinical care, including clinical practice guidelines, audio-visual materials and electronic publications. The materials may have been delivered personally or through mass mailings
Educational meetings	Healthcare providers who have participated in conferences, lectures, workshops, or traineeships
Local consensus process	Inclusion of participating providers in discussion to ensure that they agreed that the chosen clinical problem was important and the approach to managing the problem was appropriate
Educational outreach visits	Use of a trained person who met with providers in their practice settings to give information with the intent if changing the provider's practice. The information given may have included feedback on the performance of the provider(s)
Local opinion leaders	Use of providers nominated by their colleagues as *'educationally influential'.*
Patient mediated interventions	New clinical information (not previously available) collected from patients and given to the provider
Audit and feedback	Any summary of clinical performance of health care over a specified period of time. The summary may also have included recommendations for clinical action. The information may have been obtained from medical records, computerised databases or observations from patients.
Reminders	Patient or encounter specific information, provided verbally, on paper or on a computer screen, which is designated or intended to prompt a health professional to recall information. This would usually be encountered through their general education; in the medical records or through interactions with peers, and so remind them to perform or avoid some action to aid individual patient care. Computer aided decision support and drugs dosage are included.
Clinical multidisciplinary teams	Creation of a new team of health professionals of different disciplines or additions of new members to the team to work together to care for patients
	Changes in medical records systems e.g. changing from paper to computerised records
	Presence and organisation of quality monitoring mechanisms

There is an abundance of published literature on interventions to change the behaviour of healthcare professionals.[96] The Cochrane Library contained eight systematic reviews which examined the effectiveness of interventions in changing the behaviour of healthcare professionals. These interventions were education[97-100], audit and feedback[101], inter-professional collaboration[102], local opinion leaders[103], and other tailored interventions.[104] These systematic reviews and also the systematic review conducted by Davey and colleagues in 2005[11] will be discussed in context of this current literature review. These systematic reviews were based on the EPOC classification of interventions to change professional behaviour in healthcare settings *(see table 1.9)*. Also, this current literature will be presented as an update of

Davey's systematic review however there will be greater focus on organisational interventions for implementing ASPs.

1.10.3 Interventions to improve antimicrobial prescribing in hospitals

From the previous discussions, it can be seen that there common characteristics between interventions to alter professional practice and to improve prescribing. However, none of the reviews discussed so far specifically examined the interventions to improve antimicrobial prescribing in hospitals.

As previously discussed, Davey and his colleagues conducted a systematic review on hospital-based interventions used to improve antimicrobial prescribing practice.[11] The primary aim of this systematic review was to identify interventions that alone, or in combination, were effective in improving antimicrobial prescribing in hospitalised patients. The objectives of Davey's systematic review included:

- To estimate the effect of interventions on four aspects of antimicrobial prescribing such as prescribing decisions, antimicrobial regimens, duration of antimicrobial therapy and timing of surgical prophylaxis
- To estimate the effect of increasing appropriate, evidence-based antimicrobial prescribing on patient outcomes and healthcare costs. The outcomes assessed were antimicrobial prescribing and associated costs, other healthcare costs, *Clostridium difficile* associated diarrhoea, prevalence of colonisation with or clinical infection and other measures of clinical outcome.

This systematic review included 66 studies which investigated a range of interventions and were categorised according to the nature of the intervention(s) *(see table 1.10).*

Table 1.10 - The interventions for improving antimicrobial prescribing in hospitalised patients as categorised by Davey et al (2005)[11]

Persuasive interventions	Restrictive interventions	Structural interventions
General education (n=13)	Expert review of restricted drugs (n=14)	Rapid identification and susceptibility testing (n=2)
Review/recommend changes to antimicrobial therapy (n=16)	Removal/restriction (n=9)	Therapeutic drug monitoring (aminoglycoside dosing optimisation programme (n=1)
Reminders (n=8)	Compulsory order forms for restricted drugs (n=5)	
Guidelines (n=5)	Cycling/rotation (n=4)	
Audit and feedback (n=4)	Therapeutic substitution (n=3)	

Table 1.10 *(cont'd)* - The interventions for improving antimicrobial prescribing in hospitalised patients as categorised by Davey et al (2005)[11]

Persuasive interventions	Restrictive interventions	Structural interventions
Care pathways (n=3)	Automatic antimicrobial stop-order policy (n=2)	
Opinion leaders (n=2)	Compulsory interactive computer order form (n=1)	
Review/make changes to antimicrobial therapy (n=1)		

The studies focused on interventions to optimise antimicrobial therapy by either reducing (n=57) or increasing the amount of antimicrobial prescribed (n=7). Two studies examined the effect of increasing and reducing the amount of antimicrobial prescribed. Pharmacists were the intervention lead in 22 out of 66 studies. These interventions were primarily persuasive in nature (n=14) and aimed to decrease the amount of antimicrobials prescribed. Interventions were delivered by a specialist physician in infectious diseases or microbiology in 17 out of 66 studies. These interventions were primarily restrictive in nature (n=11) and mainly aimed to decrease the amount of antimicrobials prescribed. A multidisciplinary team delivered interventions in 11 out of the 66 studies. These interventions were primarily persuasive in nature (n=9) and mainly aimed to decrease the amount of antimicrobial prescribed. The intervention lead was undeclared in 16 studies but the targeted staff group and the methods of implementation were declared. Departmental physicians were the target of interventions in 4 studies which were mainly restrictive (n=2). Restrictive antimicrobial policies were used in 7 studies and computerised assistance or written feedback was used in 5 studies. Davey and his colleagues described interventions as either single component (n=44) or multifaceted (n=22) in nature. However, on examination of each study, it was found that the reported interventions were mainly single interventions which were conducted in conjunction with other supplementary or minor interventions. The findings of Davey's systematic review will be discussed in conjunction with the findings of this current literature review.

1.10.4 Restrictive interventions

There were a number of restrictive interventions reported in the literature and these interventions are presented in this section. Restrictive interventions found in the literature were pre-approval *(see section 1.10.4.1)*, removal or restriction of

antimicrobials *(see section 1.10.4.2)*, compulsory order forms *(see section 1.10.4.3)* and automatic stop orders *(see section 1.10.4.4)*.

1.10.4.1 Pre-approval (Expert review of restricted antimicrobials)

11 studies were found in the literature which investigated the effect on pre-approval or expert review strategies on the quality of antimicrobial prescribing. One study was a randomised controlled trial (RCT)[105] and 11 were interrupted time series (ITS) studies.[106-116] Three primary pre-approval or expert review strategies were reported in the literature and there were pre-approval by a consultant or clinician with specialist knowledge on infectious disease management (n=10), an antimicrobial management team (n=1) and a web-based antimicrobial approval system (n=1). These interventions were utilised before antimicrobials were prescribed or administered to study participants. In some studies, these interventions were supplemented by persuasive interventions such as audit with feedback and education by pharmacists.

Tsiata and her colleagues[105] conducted a non-blinded RCT in an internal medicine department where there were three intervention groups. This RCT was categorised as having a very high risk of bias (GRADE LOE (1^-). The intervention for Group A (n=134) was an order form which required an authorising signature and also a stop order at day 5 was used in this group. Group B (n=141) utilised an order form alone without an authorising signature however there was limited discussion on the use of stop orders in this intervention arm. Group C (n=105 patients) was the control group for this study where clinicians prescribed in the absence of restriction measures. They reported that there were no significant differences in clinical outcomes such as clinical improvement, clinical cure and death rates across the intervention arms of the study in 382 patient records. Also, the primary and secondary outcome measures were not clearly defined and there was little discussion about how there were accessed. There was no allocation concealment mechanism reported in the study and there was little discussion about randomisation was conducted. The allocation bias was unacceptable because of the differences in the participants in each arm of the study and baseline characteristics of the sample. Another limitation of this study was that there was not a clear definition of the intervention between Group B and Group C (control group), it appears that the interventions conducted in these groups were analogous. The effectiveness of this intervention in improving

antimicrobial prescribing was indeterminate. Consequently, these results should be interpreted with caution and may not be generalisable to other healthcare settings. Three ITS studies[106;107;112] investigated in the effectiveness of restricting clindamycin by pre-approval by an infectious disease clinician or consultant.

One ITS study conducted by Climo 1998 and his colleagues[106] noticed that the percentage of clindamycin-resistant *Clostridium difficile* isolates was increasing from 58% (1987 to 1988) to 91% (1993 to 1994) in their hospital. Based on this evidence, it was decided to institute a restrictive intervention of pre-approval by an infectious disease consultant prior to clindamycin use. They reported desired effects of clindamycin restriction on antimicrobial usage for example, one month post-intervention clindamycin use decreased six-fold to 170g. Also, at 5 months, clindamycin use averaged 151g per month, which equated to a reduction of 87%. Clindamycin restriction was associated with a sudden decrease in level by 2.3 CDAD cases per quarter *(p<0.001)* and a sustained decreased in slope by 3.8 CDAD cases per quarter *(p<0.001)*. There was a 92% in antimicrobial expenditure from US$35, 000 to less than US $3000 however this cost analysis was based on UBA data. Also, post-intervention, there was decreased in the number of clindamycin-resistant *C.difficile* isolates for example, pre-intervention 91% of isolates were clindamycin-resistant and post-intervention, 75% (*p<0.10*) of resistant isolates were reported at 5 months. This trend was sustained, for example, at 20 months post-intervention 39% (*p<0.001*) were clindamycin-resistant. However, there was a reported increase in the use and expenditure of other antimicrobials with similar activity such as imipenem, piperacillin and metronidazole. There was no cost analyses conducted on the costs associated with implementation of this intervention.

Clindamycin restriction was conducted in conjunction with 3rd generation cephalosporins and vancomycin in another ITS study.[107] Additionally, ampicillin/sulbactam and piperacillin/tazobactam were added to the formulary and it was suggested to be used instead of cephalosporins. They observed a sudden decrease in the use of the targeted antimicrobials for example, cefotaxime (1432 ± 283 g/mo to 164 ± 78 g/mo; *p<0.01*). However, there were no significant changes in monthly antimicrobial expenditure ($29457 ± $3866 vs. $28 065 ± $5749; *p=0.30*). Also, this intervention was not associated with a reduction in two of the microbiological outcomes for example, incidence of *Klebsiella pneumoniae* was observed as [-2.89; *p=0.205* and 0.04; *p=0.798*]. They indicated that this could be

due to shorter inpatient length of stay which could potentially limit patient exposures to resistant strains.

Pear and her colleagues[112] reported that there was 83% decrease in clindamycin use from 429g to 71g per month. Also, restriction of clindamycin was associated with a sudden reduction in level by 3.68 *(p=0.041)* and sustained reduction of 0.32 *(p=0.134)* cases per month. These outcomes were maintained after the end of the study. One important finding on this study was that clindamycin use was associated with the development of CDI [RR 9.1(4.0 to 20.4)] which was confirmed by the regression analysis conducted. There was blind assessment for the primary outcomes, data collection methods used and also infection control methods were similar at both pre-intervention and post-intervention.

Lautenbach and his colleagues[108] found that approximately one-third of vancomycin courses were non-complaint with guidelines one year after the restrictive intervention was implemented. Also, the prevalence of VRE increased for the duration of the study from 5-10% pre-intervention to 15-30% post-intervention. There were limitations associated which could have introduced a medium risk of bias into the study design. They did not distinguish between nosocomial and community-acquired isolates, this limitation is important because changes in antimicrobial use would only affect nosocomial isolates. Another limitation is that VRE prevalence data was calculated based on clinical isolates and not on actual colonisation rates. Therefore, VRE prevalence could be underestimated in their setting. An ecological approach was used to investigate the correlation between antimicrobial use and VRE prevalence; therefore it was difficult to assign causality and to control of confounders.

Two studies[110;114] reported on preapproval supplemented by a persuasive component. For example, one French study[114] which was conducted from 1997 to 2000 reported on the efficacy of pre-approval of the most expensive antimicrobials in conjunction with feedback to prescribers who were not compliant to their local prescribing protocol. Although, they reported that there was a beneficial economic impact of multi-component interventions for example the mean cost of antimicrobials per patient decreased from US$ 13.8 in 1997 to US$11 in 2000 *(p<0.001)*. They indicated that the decrease in antimicrobial expenditure was not solely attributable to the interventions because there was an increased expenditure in cancer agents

during the study. Therefore, this intervention was not associated with any significant change in level of antimicrobial expenditure *(p=0.981)* and a non-significant reduction in level by $0.498 per patient per year *(p=0.299)*. Over the 4-year period, the rates of MRSA and ceftazidime-resistant pseudomonads were sustained post-intervention and there was also a significant reduction in *Enterobacteriaceae* producing ESBL rates from 12.5% to 3.6% *(p<0.001)*. However, there was no pre-intervention data reported so therefore these results should be interpreted with caution.

1.10.4.2 Removal or restriction of antimicrobials

There were 10 studies[117-126] found which examined the impact of removal or restriction of antimicrobials on antimicrobial prescribing. One cluster CCT was categorised as GRADE LOE (1^+), eight ITS studies were categorised as GRADE LOE ($2^+/2^-$) and one ITS was categorised as GRADE LOE (2^-) which indicated that this study had a high risk of bias. There were two main methods of removal or restriction reported in the literature and they were removal of targeted antimicrobials from the drug formulary and from ward stocks.

The intervention leads for these were ID physicians (n=4), pharmacists (n=1) and there was no intervention lead was declared in 5 studies. Generally, the primary intended aim of this intervention was the restriction or reduction in the use of antimicrobials such as cephalosporins.[114;115;119;120;121;122] The majority of studies reported on microbiological outcomes such as the reduction of GRE, CDI and other resistant microorganisms such as *E.cloacae*. Post-intervention, most studies reported a significant decrease in resistance to targeted antimicrobials.

One cluster controlled clinical trial (CCT) (GRADE LOE (1^+)[120] was conducted which investigated the effect of a restrictive change in policy from penicillin and tobramycin to amoxicillin and cefotaxime for neonates requiring ventilation with suspected pneumonia. They found that the emergence of resistance was higher in the amoxicillin and cefotaxime period *(see table 1.10)*. Furthermore, during the amoxicillin and cefotaxime regime, it was observed that there were a higher number of incidences of either tobramycin resistant or cefotaxmine resistant strains and also cefotaxmine resistant Enterobacter *spp. (see table 1.11)*. Overall, colonising events occurred 18 times more frequently in units where the amoxicillin/cefotaxime regime was used.

Table 1.11 - Risk of colonisation with resistant gram-negative bacilli and antibiotic regimen[120]

Colonisation strain	Penicillin/Tobramycin regime	Amoxicillin/ cefotaxime regime	Relative risk (95%CI)
Gram-negative bacillus resistant to cefotaxime	6·8 (16/2339)	21·4 (41/1914)	3·14 (1·76 - 5·56)
Gram-negative bacillus resistant to tobramycin	1·2 (3/2519)	0 (0/2706)	-
Gram-negative bacillus resistant to cefotaxime or tobramycin	8·9 (19/2128)	21·4 (41/1914)	2·42 (1·41 - 4·15)
Cefotaxime-resistant Enterobacter *spp.*	6·8 (15/2197)	20·3 (39/1917)	2·98 (1·64 -5·38)
Gram-negative bacillus resistant to empiric therapy of unit*	1·2 (3/2519)	21·4 (41/1914)	17·98 (5·57 - 58·01)

Nb. Data was reported as colonising events/patient days at risk x 1000

It was also found that colonisation with pathogens other than gram-negative bacilli, such as *Candida spp.*, *Enterococci*, *Haemophilus spp*., *Listeria monocytogenes*, coagulase-negative *staphylococci, Staphylococcal aureus*, and group A and group B streptococci, did not significantly differ between the two regimens however these data were not reported. Therefore, it can be seen that this intervention had little to no intended effect on the colonisation by Gram -ve bacilli resistant to cefotaxime or tobramycin.

One US study[121] reported on the effects of removing restrictions for nine antimicrobials from their formulary. This intervention was unsuccessful; for example, they observed a 158% increase in the use of *'restricted'* antimicrobials which subsequently resulted in increased expenditure from US$154542 to US$313905. From these results, it can be seen that utilising a restrictive policy can produce an immediate reduction in targeted antimicrobial use and in some instances, reduction in targeted antimicrobial expenditure and resistant isolates however there may be a shift in antimicrobial class use or an increased compensatory use in antimicrobials with a similar spectrum of activity. Also, the cost effectiveness of these interventions were difficult to determine because studies did not report on the costs required to implement these strategies.

Another ITS study[122] reported on the impact of the removal of cefotaxime and ceftriaxone for the treatment of severe sepsis or pneumonia. The intended outcomes were reduction in antimicrobial expenditure and also CDAD rates. Prior to implementing the restrictive policy, the number of CDAD cases were falling at a rate of -3.8 cases per quarter *(p=0.115)*. Post intervention, they reported that they observed a strong relationship between ceftriaxone consumption and CDAD cases *(see figure 1.4)*.

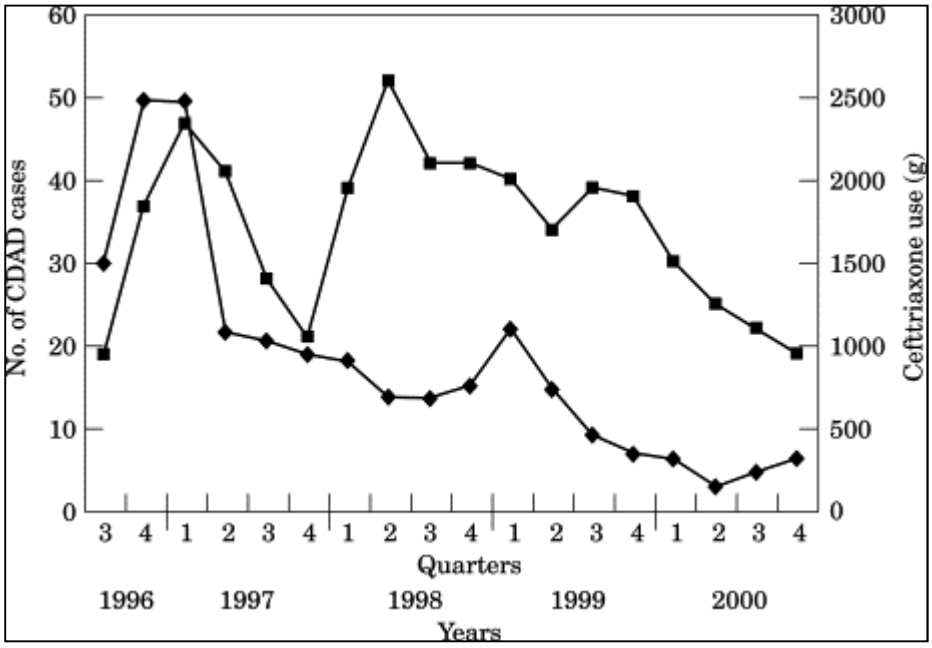

Figure 1.4: Ceftriaxone use and CDAD cases [122]

Also, they reported that the intervention was effective based on these results. There was a sudden decrease in level by +19.7 cases per quarter *(p=0.074)* and a sustained increase in slope by +4.7 cases per quarter *(p=0.073)* despite maintaining good control of antimicrobial use. Furthermore, when there was a substitution made in the policy from ceftriaxone to levofloxacin, there was a non-significant change level by -5.8 cases per quarter *(p=0.525)*.

One UK study[123] which examined the effect of changing their restrictive antimicrobial policy in an elderly unit. For example, patients admitted with suspected infection were prescribed IV benzylpenicillin 1.2 to1.8 g every 6 hours to cover streptococcal infections, including those caused by *Streptococcus pneumoniae*, and IV trimethoprim 200 mg twice daily to cover urinary tract pathogens and *Haemophilus influenzae*. This intervention was led by a pharmacist and accompanied by the removal of oral cefuroxime for the pharmacy. They observed that there was

reduction in the number of CDI per month by 3.22 cases *(p=0.120)*. They also observed a reduction in the total antimicrobial costs from £21,481 to £12,859. However, the authors were cautious in ascribing a causal relationship between the introduction of the new policy and the incidence CDI due to the uncontrolled nature of the study. The efficacy of the intervention was dependent on the timing of the intervention and the relative timing of the reduction in the incidence of infection in order to establish a causal relationship.

1.10.4.3 Compulsory order forms

The impact of using compulsory order forms was investigated in three studies.[127-129] One RCT was categorised as GRADE LOE ($1^{+}/1^{-}$) and two ITS studies were categorised as GRADE LOE ($2^{+}/2^{-}$) and (2^{+}) respectively. The intervention leads for these studies were pharmacists (n=2) and a multidisciplinary team (n=1). All studies reported that compulsory order forms were effective in improving antimicrobial prescribing. For example one ITS study[129] examined the impact of a structured compulsory form on three classes of antimicrobials, that is, 1st generation cephalosporins, 3rd generation cephalosporins and aminoglycosides. This intervention was supplemented by an educational programme which included lectures conducted up to week 102 of the study. They reported a reduction in incorrect prescriptions for aminoglycosides (47%), ceftazidime and/or cefotaxime (7.3%) and also a 20% reduction for incorrect surgical prophylaxis prescriptions. However, the order form had no significant impact on the in correct prescribing of cephradine/cephalothin. There were no data on patient outcomes or costs associated with implementing this intervention.

More recently, one French cluster controlled trial [128] has been published which specifically examined the impact of compulsory stop orders on antimicrobial prescribing. This intervention was pharmacist-led and was composed of other supplementary interventions such as audit and feedback by specialists in infectious diseases. These interventions were supported by a ward-facing Operational Multidisciplinary Antibiotic Team (OMAT) which included a microbiologist. They found that this intervention was effective in reducing the use of 3rd generation cephalosporins (142.5 vs. 104.5; *p=0.186*), and glycopeptides (168.1 vs. 39.5; *p=0.006*). Also, there was reduction in antimicrobial consumption by 33.6% in the intervention group after the implementation of the OMAT. However, this study was

subject to selection bias due to lack of randomisation of patients on the 17 study wards. Also, the reported antimicrobial usage data was only due a selected portion of antimicrobial classes which affects the generalisability of this study. Due to the low power of the study, they were unable to detect significant variation in the overall consumption. For example, the lack of difference between the groups for ceftazidime, cefepime, 3rd generation cephalosporins and linezolid were probably due to lack of power. The authors recommend that additional outcome measures such as antimicrobial resistance and patient outcomes such as mortality are required fully describe the impact of interventions.

1.10.4.4 Automatic stop orders

Automatic stop orders were investigated in three studies found in the literature.[130-132] Two RCTs was categorised as GRADE LOE ($1^{+}/1^{-}$) and the ITS study was categorised as GRADE LOE ($2^{+}/2^{-}$). The intervention lead was unclear and reported that initially this restrictive intervention was effective in reducing the duration of antimicrobial therapy, LOS and antimicrobial costs. For example, one ITS study[131] examined the impact of a three part strategy to improve antimicrobial prescribing. This intervention consisted of a 3-day automatic stop order for all antimicrobials, restriction of eight antimicrobials by a compulsory order form and also automatic therapeutic substitution (interchanges). This intervention was supplemented by dissemination of antimicrobial guidelines via newsletters, educational ward rounds, wall posters and pocket charts. Post-intervention, the difference between pre and post-intervention slopes was one vancomycin units per month *(p=0.01)* they reported that the expenditure on antimicrobials dropped by 40% which equated to savings of $621252. Annual cost savings were reported in the use of ceftazidime ($129,000), imipenem ($35,000) and vancomycin ($6,000). However, the costs associated with the implementation of these interventions were unclear.

One US RCT[132] reported on the impact of a stop order, which based on the results of an assessment at day 3 based on Clinical Pulmonary Infection Score (CPIS) and sputum microbiology . If CPIS was greater than 6 at day 3 then IV ciprofloxacin was stopped by study investigators. This study was conducted in medical and surgical ICUs reported a significant reduction in patients on antimicrobial therapy for >3 days in the study group (28% vs. 97%) and LOS on ICU (9.4 days vs. 14.7 days; *p=0.04*). Also, the rate of antimicrobial resistance and/or superinfections was also reduced

when comparing the study and control groups (15% vs. 35%; *p=0.02*). There was no significant difference in mortality between the intervention and study groups (13% vs. 31%). This study was not blinded; bias was introduced into the study as they observed that physicians prescribed fewer antimicrobials for a shorter duration in patients which were randomised to standard therapy. Additionally, it was recognised that the administration of multiple broad-spectrum antimicrobials for prolonged duration did not decrease outcomes. However, the protocol was terminated because it was deemed unethical to continue the study.

More recently, one RCT[130] was conducted in a US hospital examining the impact of an *'antibiotic discontinuation policy'* on antimicrobial prescribing for patients with clinically suspected ventilator-associated pneumonia (VAP). They found that this intervention was effective in reducing the duration of antimicrobial therapy (6.0 ± 4.9 days vs. 8.0 ± 5.6 days, *p=0.001*) however ICU LOS (6.8 ± 6.1 days vs. 7.0 ± 7.3 days, *p=0.798*) and mortality (32.0% vs. 37.1%; *p=0.357*) was statistically similar between the intervention and control group. The generalisabilty of this study is limited since it was conducted in a single intensive care unit. There were no standard criteria for the diagnosis of VAP by study physicians. Other limitations were that the discontinuation policy was only implemented when the study physicians were available during weekdays. Also, there was attrition bias due to loss of 12 patients from the study.

1.10.5 Persuasive interventions

Persuasive interventions can be categorised as interventions which do not have a restrictive component inherent in their design. There were a number of persuasive interventions found in the literature which was improving AMS in hospitals. These were audit and feedback interventions *(see section 1.10.5.1)*, educational interventions *(see section 1.10.5.2)*, reminders *(see section 1.10.5.3)* and antimicrobial (treatment and prophylaxis) guidelines *(see section 1.10.5.4)*. The target drugs for these interventions were mainly aminoglycosides, cephalosporins, glycopeptides such as vancomycin and clindamycin. Persuasive interventions were generally multi-component interventions as opposed to single component interventions.

1.10.5.1 Audit and feedback (Review/recommend changes to antimicrobials)

This intervention was the commonly reported persuasive intervention used to promote AMS. EPOC describes this type of intervention as *'any summary of clinical performance of health care over a specified period of time. The summary may also have included recommendations for clinical action. The information may have been obtained from medical records, computerised databases or observations from patients.' (see table 1.9)*

Four RCTs[133-136] and three ITS studies[137-139] were identified from a Cochrane systematic review on improving antimicrobial prescribing in hospitals.

The intervention leads for these interventions were mainly pharmacists. [133;134] However, some studies utilised a multidisciplinary approach in implementing this intervention such as feedback provided by a pharmacist in conjunction with an ID physician.[135;136] For example, the feedback or advisory service to antimicrobial prescribers was provided by pharmacists or ID physicians or by both staff groups. The description of the content and the frequency of audit and feedback were poorly described in these studies.

One US RCT[133] (GRADE LOE: $1^{+}/1^{-}$), reported on an audit and feedback intervention that was pharmacist-led and was targeted at discontinuing intravenous antimicrobials or switching patients from intravenous therapy to oral therapy for patients receiving antimicrobials for three to four days. The mean number of IV antimicrobial days was 1.04 days (95% CI; 0.60-1.48) in the intervention group versus 2.02 days (1.30-2.73) in the control group. Also, they were able to discontinue IV antimicrobials within 24 hours of initiation of therapy for example this was achieved in 73% at Hospital A and 90% at Hospital B. Also, they reported that the mean antimicrobial costs were lower in the intervention group than the study group [$19.82 (95%CI: $9.86-29.77) vs. $35.84 (95%CI: $23.42 - 48.27, *p=0.03*)]. They estimated that the costs of implementing the intervention was $15 000 Hospital A and $7 200 and Hospital B. However, a sensitivity analysis was not conducted so therefore these cost data may not be generalisable to other healthcare settings. This study had a number of other limitations such as power calculations were not used to determine sample size and risk adjustments were conducted for institution-specific effects. There was no discussion regarding the generalisability of this study.

Another RCT[134] (GRADE LOE: $1^{+}/1^{-}$),examined the impact of pharmacist-led audit and feedback to prescribers who were non-compliant to the cefotaxime guidelines. They conducted a univariate analysis and reported that this intervention was effective across the prescribing criteria (*see table 1.12)* for example, the dosage was appropriate for prescription in the intervention group [94% vs. 86%; *p=0.018*).

Table 1.12: Proportion of cefotaxime guidelines meeting evidence-based guidelines[134]

Prescribing criteria	Non-intervention group	Intervention group	*p* value[a]
Indication (%)	117/147 (80)	132/162 (81)	0.67
Dosage (%)	126/147 (86)	152/1625 (94)	0.018
Overall[b] (%)	102/147 (69)	122/162 (75)	0.24
Mean duration of therapy (SD)	4.8 (4.6)	4.3 (3.1)	0.28
Mean cost per treatment (SD)[c]	$245 (337)	$198 (162)	0.32

Nb. [a]Determined by chi-squared statistic, [b]Both indications for use and dosage were appropriate and [c]Mean difference between groups was $47 (p=0.32). A log transformation was performed on the data prior to the application of the unpaired t-test.

A multivariate analysis showed that there was improved prescribing when pharmacists provided audit and feedback and that staff physicians were likely to prescribe more appropriately than residents (OR=4.86; *p=0.12*). Other variables were significantly associated with appropriate prescribing such as longer duration, older patients and in high risk patients with renal insufficiency and immunosuppression where patients were 5 times and 3 times, respectively, more likely to receive appropriate therapy. Overall, pharmacists were only able to improve cefotaxime usage by 6% but this increase was not statistically significant. Also, they had a very limited effect on the prescription of cefotaxime for inappropriate indications. Pharmacists were able to achieve a statistically significant improvement in appropriate cefotaxime dosage. However, the results of this study should be interpreted with caution due the study's limitations. Firstly, although 332 patients were randomised by a computer generated list, bias was introduced into the study because 13 patients were removed from the control group by the study pharmacist due to patient safety issues. Additionally, six patients were removed because study pharmacists suggested cefotaxime before the order was written and also four patients removed because orders were written on units that were not serviced by clinical pharmacists. All aspects of data collection were conducted by study

pharmacists instead of a blinded third party due to funding limitations which introduced further bias into the study.

Two RCTs examined the effect of utilising a multidisciplinary approach to audit and feedback to antimicrobial prescribers.[135;136] One US RCT[135] (GRADE LOE:1^-), this categorisation indicated that this RCT has a high risk of bias. It was conducted over a 3-month period examined the impact of a pharmacist and an ID physician on antimicrobial prescribing. This intervention was targeted at patients on 10 parenteral antimicrobials including vancomycin, ciprofloxacin, and cefuroxime for 3 or more days. The primary outcomes reported were clinical response, microbiological response and antimicrobial costs. However, the costs associated with implementing this intervention were not reported. They reported that only 85% of suggestions to alter therapy were implemented by prescribers. Clinical response rates were similar between study groups (79.5% vs. 80.6%) and microbiological response rates were higher in the intervention group (9.4% vs. 5.1%) and were statistically significant. There were no statistically significant differences between the intervention and control group in terms LOS, mortality and readmission rates. Antimicrobial-associated costs per patient were less in the intervention group ($1287.12 vs. $1673.97; *p=0.05*) and similar results were obtained for IV antimicrobials. There were limitations associated with this study for example power calculations were not conducted to determine the sample size required to detect significant differences between study arms. Also, 13.1% of the original study sample was excluded from the study and there was little discussion about the reasons for this decision, therefore there was attrition bias introduced into the study.

Another US RCT[136] (GRADE LOE:1^+) investigated the effect of utilising a MDT which consisted of pharmacist, ID physician and a clinical microbiologist on prescribing. The primary outcome was LOS after randomisation for 252 patients, which equates to 93% of the total randomised sample (n=272). There was a 3.3 day *(p=0.0001)* difference reported in the LOS between the study groups (9 days vs. 5.7days). LOS was adjusted for complex interventions and it was statistically significantly lower for both complex *(p=0.18)* and simple interventions *(p=0.001)*. Also, they reported that the acceptance of recommendations by physicians were 89%. The costs associated with this intervention was also analysed by a Weibull regression and they reported that the Weibull median costs were lower in the intervention group ($9153 vs. $12207). Also, median costs for additional services such as radiology were reduced

by $4404 per intervention. This study had a low risk of bias, for example blinded assessment of the primary outcome was conducted and also risk adjustments were conducted for potential confounders. However, as previously discussed, 17% (n=20) of the randomised patients were excluded from the study post-randomisation, which could have introduced attrition bias. The authors indicated that the success of this intervention could be partly due to improved education to prescribers regarding antimicrobial therapy.

More recently, ten studies have been published which examined audit and feedback mechanisms to improve antimicrobial prescribing. These studies were six RCTs[140-145] and four ITS studies.[146-149]

In some studies, audit with feedback was not reported as an effective intervention in some studies. For example, one US RCT[141] (GRADE LOE:1^{+}), reported on the effect of TRAPE (Trial to Reduce Antimicrobial Prophylaxis Errors) which was part of the Project to Monitor Indicators which was part of a collaboration between SHEA, CDC and the Joint Commission and was conducted in 44 acute hospitals. This intervention groups were randomised to receive a comparative feedback report only or a feedback report plus enrolment in a Quality Improvement (QI) collaborative. This intervention was targeted at infection control and surgical and was focused on improving the timing of administration of pre-surgery antimicrobial prophylaxis. The QI component included utilising opinion leaders *(see table 1.9)* who were experts in antimicrobial prophylaxis to develop QI strategies. They reported that comparative audit and feedback in conjunction with a quality improvement collaborative did not significantly improve appropriately timed dose of antimicrobial prophylaxis. For example, intervention hospitals only improved by 6.7 percentage points (CI, 0.2 to 1.31) percentage points. There was little difference between the two study groups (-3.8 percentage points [-13.9 to 6.2 percentage points]). Furthermore, the proportion of patients receiving surgical prophylaxis for no more than 24 hours post-surgery rates increased for both study groups. The bundle measure, containing the timing of antimicrobial therapy, choice and duration, improved in both groups but the between group difference was not substantial. There was an improvement observed in the bundle measure for cardiac and knee surgeries but this was due to the increased proportion of patients not receiving an extended course of postoperative antimicrobials. This QI collaborative had limited effectiveness in improving the timing antimicrobial prophylaxis. This could be due to the proportion of patients receiving

prophylaxis or the recommended drug was high at baseline. This study was conducted when there was a national awareness of antimicrobial prophylaxis. Another RCT[142] (GRADE LOE:1^{+}/1^{-})reported that audit with feedback did not significantly improve antimicrobial consumption (median [IQR], 8 [4-12] vs. 10 [6-16] DDDs per patient; *p=0.04*) and there were no significant differences between groups when each antimicrobial were analysed. They observed a significantly lower duration of therapy in the intervention group (median [IQR, 4 [3-7] vs. 6 [4-10]; *p=0.002*) and the greatest reduction was observed in the prescription of carbapenems. Also, they reported that uptake of suggestions was only 50.5% for discontinuation or modification of therapy. Levofloxacin was less frequently discontinued by clinicians than carbapenems (70%; *p=0.03*) or vancomycin (87.5%; *p=0.01*). There was also little difference in the discontinuation of therapy between medical and surgical wards (50.8% vs. 51.5%). Additionally, there were no differences between groups in terms of readmission within one month, LOS and 6-month post-discharge mortality *(see table1.13)*. Also, this intervention did not reduce antimicrobial-related expenditure.

Table 1.13: Comparison of antibiotic consumption and outcomes between intervention and control groups[142]

Outcomes	Intervention group (n=146)	Control group (n=132)	*p*-value
Total number of defined daily doses (DDDs) of the targeted antibiotics per patient, median (IQR)	8 (4–12)	10 (6–16)	*0.04*
Levofloxacin (n=166)	8 (6–14)	10 (6–18)	*0.17*
Vancomycin (n=47)	6 (4–11.63)	9 (3.68–13.35)	*0.41*
Carbapenem (n=65)	6 (4- 10.5)	8.75 (5.81–12.0)	*0.13*
Total number of days receiving the targeted antibiotics per patient, median (IQR)	4 (3–7)	6 (4–10)	*0.002*
Levofloxacin (n=166)	4 (3–7)	5 (3–8)	*0.16*
Vancomycin (n=47)	6 (4–12)	9 (4–13.25)	*0.39*
Carbapenem (n =65)	4 (3–7)	8 (6.75–12)	*<0.0001*
Length of hospital stay, median (IQR)	14 (8–25)	13.5 (8–21)	*0.45*
Readmission within 1 month, no. (%)	31 (21.2)	20 (15.2)	*0.22*
In-hospital mortality, no. (%)	40/140 (28.6)	33/129 (25.6)	*0.68*
Total number of DDDs per patient[a], median (IQR)	11.05 (6–18.2)	10 (6–16.5)	*0.13*
Total antibiotic charges per patient[a] in euros, median (IQR)	100.0 (39.4–224.5)	118.5 (37.2–299.3)	*0.45*

IQR: interquartile range, CI: confidence interval, DDDs: defined daily doses
[a]Includes the costs of the alternative/s antibiotic/s used in the intervention group

There were a number of limitations associated with this study. Firstly, bias was introduced because the investigator was not blinded to study outcomes and solely

collated the data in one study arm. Secondly, attrition bias was introduced because only 278 (94%) randomised prescriptions were included in the analysis however there was a clear rationale provided for the exclusion of prescriptions. The authors reported that there *was 'a certain influence'* on prescribing practices in the control group but these were not described. These factors may have contributed to the similarity in outcomes for both the intervention and study groups.

1.10.5.2 Educational interventions

There were 11 studies[150-160] identified in the literature which investigated the effect of educational interventions. The educational interventions used to improve antimicrobial prescribing in hospitals were multifaceted. In other words, there was a main or primary intervention which was supplemented by other single or multiple interventions. The primary educational interventions reported included educational lectures or meetings, academic detailing and educational outreach visits. These primary interventions were supplemented by other interventions such as reminders, posters, guideline dissemination, and most frequently audit and feedback by pharmacists. The main intervention leads were a multidisciplinary team (n=4), local expert (n=2), pharmacist (n=2), an obstetrician (n=1) and was undeclared (n=1). Most of these interventions were targeted at reducing the amount of antimicrobials prescribed. Studies reported that these interventions were effective in their settings. Two RCTs[155;157] showed the educational interventions such as academic detailing could have a positive effect on prescribing. For example, one US RCT[155] (GRADE LOE:$1^{+}/1^{-}$), investigated the effect of a multifaceted educational intervention. They reported that the appropriate use of parenteral antimicrobials according to pneumonia guidelines increased in both intervention and control arms and was greater in the intervention arm (50% to 81.8% vs. 64.5% to 69%; *p=0.06*). A multivariate analysis which controlled for pneumonia severity and pre-intervention differences in 30-day mortality showed that there was no significant differences in 30-day mortality between the groups for episodes requiring parenteral antimicrobials *(p=0.16).* However, there were limitations associated with this study. There was no power calculations done to determine the sample size required to detect differences between the intervention and control group for example the sample size was inadequate to determine the impact of guidelines on mortality. Also, there was may

have inconsistent recording for the indications for either parenteral or oral antimicrobials which subsequently impact the risk adjustments analyses conducted. Wyatt and colleagues[159] (GRADE LOE:1^{+}), investigated the impact of educational outreach visits in conjunction with opinion leaders *(see table 1.9)* to improve uptake of clinical guidelines and Cochrane pregnancy and childbirth reviews. In this study, the opinion leaders were a lead obstetrician and midwife which conducted a single visit to obstetric units of intervention hospitals and outlined implementation strategies and discussed methods of applying evidence from the Cochrane reviews. It was anticipated that after nine months after there may be an improvement in the uptake of evidence which would be demonstrated by four clinical markers such as the use of antimicrobial prophylaxis in caesarean section procedures. The frequency of administration of prophylaxis was not significant between the intervention and study hospitals and at similar rates of increase was observed in both intervention arms (63% to 71% vs. 54% to 74%). The costs associated with each hospital were calculated at £860 in 1995. Potentially, more frequent educational visits may have improved uptake of guidelines but this may not cost effective or feasible. Also, the authors did not request that participating hospitals nominated local opinions leaders which were able to identify local barriers to implementation. The 9-month follow-up period may have been insufficient time to observe the effectiveness of this intervention.

More recently, there were three studies[151;156;160] were found which examined education of antimicrobial prescribers as the primary intervention. Buising and his colleagues [151] (GRADE LOE:$2^{+}/2^{-}$), investigated the impact of academic detailing on prescribing. The efficacy of academic detailing was compared to a computerised decision support system (CDSS). Academic detailing involved training a MDT to provide academic detailing or one to one training to prescribers. Also, posters and laminated cards were used to provide information about severity assessment and appropriate antibiotic choices for CAP. They found that there was greater compliance to guidelines during the CDSS phase of the ITS study. One cluster RCT[156] (GRADE LOE:$1^{+}/1^{-}$), examined the impact of local opinion leaders provided education to prescribers for patients with lower respiratory tract infections. This educational intervention was supplemented by audit and feedback on individual prescribing practices and also the dissemination of critical care pathways to prescribers. They tailored these interventions to overcome locally identified barriers

to guideline compliance. They reported that this multifaceted approach was moderately effective in changing prescribing practice for example compliance to treatment guidelines increased from 50.3% to 64.3% [OR, 2.63; 95%CI, 1.57 to 4.42; *p=0.008*] and also the rate of adaption of antimicrobial doses to renal function from 79.4% to 95.1% [OR,7.32; 95%CI, 2.09 to 25.7; *p=0.02*]. Also, for streamlining of therapy there was a 5.7% improvement in intervention hospitals however adherence to this indicator was not statistically significant (OR, 1.88:95%CI, 0.32-11.03; *p=0.46*). This study was categorised as having a medium risk of bias and there were limitations associated with this study. For example, the data were collected study investigators who are not blinded with respect to primary and secondary outcomes. The study did not assess the effect of this multifaceted intervention on patient safety. Also, this study did not provide any new information about the sustainability of this intervention.

There have been three systematic reviews which investigated the impact of educational interventions on professional practice and health care outcomes.[97;98;100] The effectiveness of educational outreach visits was investigated by O'Brien and his colleagues. They concluded that educational outreach visits alone or in combination with other interventions had relatively small and consistent effects on prescribing but these effects were significant due to the number of patients that are affected by prescribing decisions. The impact of continuing education meetings and workshops was investigated by Forsetlund et al (2009) and they concluded that mixed interactive and didactic educational interventions were more effective that interactive interventions only.[97] The systematic review on the use of printed educational material was conducted by Farmer et al (2011) found that this intervention was associated with improved process outcomes but not on patient outcomes. They also concluded that there is insufficient description in the included studies about the materials used and in which settings there were most effective.[100]

1.10.5.3 Reminders

EPOC describes this intervention as '*Patient or encounter specific information, provided verbally, on paper or on a computer screen, which is designated or intended to prompt a health professional to recall information. This would usually be encountered through their general education; in the medical records or through interactions with peers, and so remind them to perform or avoid some action to aid*

individual patient care. Computer aided decision support and drugs dosage are included' (*see table 1.9)*. There were five studies[161-165] which reported on the effectiveness of using reminders on antimicrobial prescribing. Both computerised and non-computerised reminders were used in these studies. Computerised reminders were reported as effective interventions in reducing and increasing antimicrobial prescribing. One US RCT (GRADE LOE:$1^{+}/1^{-}$) was conducted by Shojania and colleagues[163] and investigated the impact of computerised guidelines for vancomycin ordering at the time of initial vancomycin ordering and after 72 hours of therapy. The primary outcomes included number of vancomycin orders and duration of vancomycin therapy. They reported that computerised reminders resulted in fewer orders written (11.3 vs. 16.7; *p=0.04*), fewer patients on vancomycin (7.4 orders vs. 10.3 orders; *p=0.02*) and also a reduction in therapy duration (26.5 days vs. 41.2 days; *p=0.05*). A regression analyses on the percentage of patients receiving vancomycin showed that post-intervention both the slope *(p=0.04)* and vertical *(p=0.01)* intercept changed significantly. These results should be interpreted with caution due to study limitations for example the baseline data was unclear so therefore it was difficult to ascertain the validity of reported effect of this intervention. Also, there may have been contamination of the control group who potentially became aware of the intervention. Additionally, the authors reported that a Hawthorne effect may have produced reductions in vancomycin ordering in both groups because study physicians were not blinded for the patient outcomes. However, one US RCT[164] (GRADE LOE:1^{+}), investigated the effect an automated reminder system which aimed to increase antimicrobial prophylaxis for cardiac surgery. This intervention consisted of an intraoperative audible alert produced by the computer in the operating theatre for procedures which lasted more than 4 hours post administration after the first dose of cefazolin. The primary outcome of this study was to improve compliance to antimicrobial prophylaxis guidelines which recommended that patients undergoing cardiac surgery should receive intraoperative re-doses of after the first preoperative dose of cefazolin if the procedure lasts more than 4 hours. They reported that patients received intraoperative re-dosing was significantly higher in patients in the intervention group (68% vs. 40%; *p<0.001*) (*see figure 1.5)*. However, the absolute rate of surgical site infection were control group (6%), intervention group (4%) vs. 10% (pre-intervention) . A multivariate analysis was conducted and it found that the effect of the reminder system remained

significant after adjustment for surgery duration, therefore reminder and alarm [OR 3.31, CI 1.97 to 5.56; *p<0.001*] and duration of surgery [OR 1.62, CI 1.30 to 2.03; *p<0.001*].

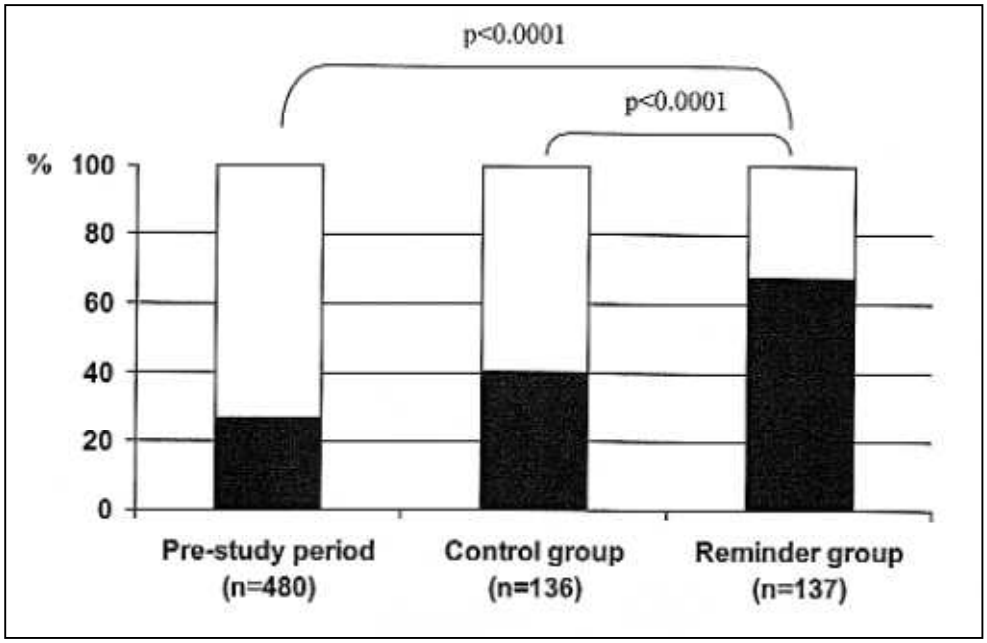

Figure 1.5: Proportion of patients who received an intra-operative re-dose of a prophylactic antibiotic.[164]

More recently, one RCT[162] (GRADE LOE:1^{+}/1^{-}) was identified which examined the effectiveness of non-computerised reminders on antimicrobial prescribing. Senn and his colleagues investigated the use of a mailed questionnaire on antimicrobial prescribing for patients on IV antimicrobial therapy. They reported that there was a trend towards shorter elapsed time to therapy modification in the intervention group *(see figure 1.6).*

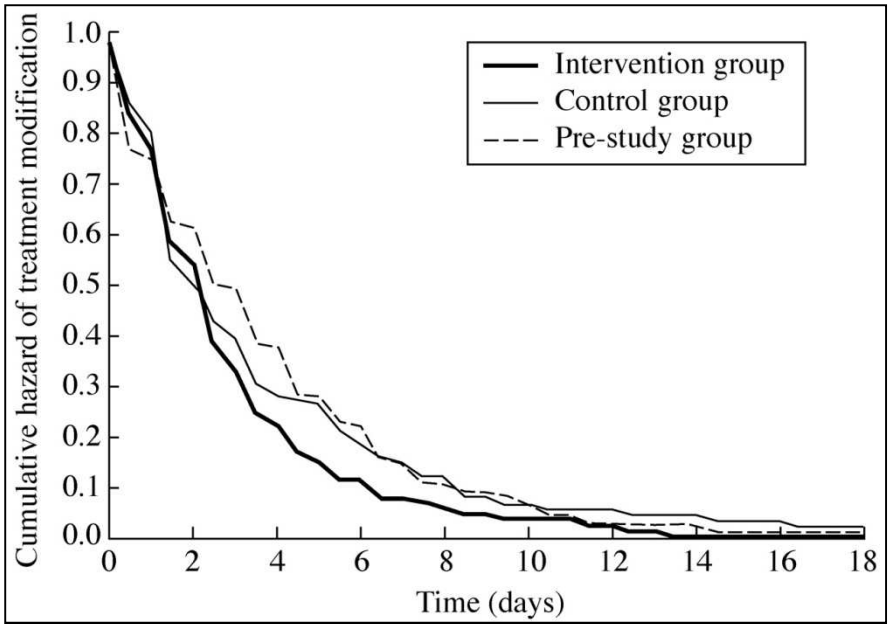

Figure 1.6: Time elapsed (in days) from inclusion until first modification of the intravenous antibiotic therapy: comparison between the intervention group (thick line), the control group (narrow line) and the pre-study group (broken line).[162]

They found that this intervention was effective in reducing the time to modify IV therapy (adjusted hazard ratio for modification was 1.28 (95%CI 0.99-1.16, *p=0.06)* which corresponded to a 14% shortening of the total days from initial antibiotic therapy to modification of antimicrobial therapy. The patient outcomes were similar in both groups; however, there were no detrimental effects reported which were associated with modification of therapy. However, these results should be interpreted with caution because attrition bias was introduced into this study. Nine patients were excluded because they violated the inclusion criteria of this study.

1.10.5.4 Antimicrobial guidelines

A systematic review reported on four ITS studies[166-169] which examined the effect of guidelines on antimicrobial prescribing. Each study was categorised as GRADE LOE ($2^+/2^-$) which indicated that they had a medium risk of bias. The intervention leads for these studies were MDT which included ID physicians and microbiologists (n=3) and pharmacist only (n=1). The designated specialty of the local expert was undeclared. Three out of the four studies reported an immediate and sustained effect of guidelines. For example, one ITS study conducted by Berild and colleagues[167] reported a sudden reduction in level by 6.9 DDD per 100 bed days *(p=0.011)* and by £181/100 bed days *(p=0.006).* However, this intervention was supplemented by

lectures on antimicrobial prescribing for newly employed doctors and also meetings with ID physicians and microbiologists. Another ITS study[168] reported that they could not identify any significant change in terms of length of stay (LOS) or hospital charges after guideline implementation. This could be as a result of these outcomes decreasing before the start of the intervention.

Additionally, there were eight studies which were one RCT[170] (GRADE LOE: 1^-) and seven ITS studies[171-177] which aimed to investigate the efficacy and impact of antimicrobial treatment guidelines on antimicrobial prescribing. These studies mainly focused on reducing antimicrobial consumption and improving compliance to guidelines. Each ITS study reported reduced antimicrobial consumption for example one ITS study[174] GRADE LOE ($2^+/2^-$) reported a reduction in the use of fluoroquinolones and cephalosporins. Another ITS study[175] GRADE LOE ($2^+/2^-$) focused improving compliance by using a bundle approach, which consisted of multiple interventions. The bundle consisted of IV to oral switch guidelines, antimicrobial guidelines and an educational programme, notes for the restriction of ciprofloxacin on lab reports and also concurrent audit and feedback. They reported a number of limitations in their study for example, they suggested that the ciprofloxacin resistance rates could have been biased by the occurrence of outbreaks and also more significantly changes in the infection control policy. Another ITS study[171] GRADE LOE ($2^+/2^-$) also examined the impact of guidelines developed by a MDT of opinion leaders. This intervention was supplemented by a strong educational component such as distribution of pocket reminder cards, promotion of standardised orders, and the development bilingual patient education materials. This multifaceted intervention was associated with an increase in antimicrobial guideline compliance from 78.1% to 83.4% *(p=0.003)*.

Foy and his colleagues[170] conducted a cluster RCT in 26 gynaecology wards (n=1474) in Scotland which conduct induced abortion and they investigated the use of antimicrobial prophylaxis for lower genital tract infection. This was done as part of a multifaceted strategy to improve the care of patients undergoing abortions. They found that there was very little difference in compliance to guideline recommendations in the intervention group [100(95.2-100) vs. 96.5(90.1-98.6) OR 1.70(0.71 to 5.99)]. A high risk of bias was introduced into the study because the blinding procedures were subject to contamination between the study groups. Also, the knowledge of the trial among study clinicians could have exerted Hawthorne

effects which could have led to the improved performance observed in the control arm. Ansari et al (2003)[176] (GRADE LOE: 2^{+}) demonstrated that the use of guidelines could reduce the expenditure on Alert antimicrobials. They reported a significant decrease in the use and costs of Alert antimicrobials. The most significant change was observed for teicoplanin and ceftazidime. Also, they reported a significant change in slope therefore the overall usage of Alert antimicrobials decreased by decreased by 0.27 DDD/100 bed-days per month (95% CI: 0.19 - 0.34, *p<0.0001*). However, on analysis of the trend data for all targeted antimicrobials, they found that there was no significant change in level. They concluded that in the absence of this intervention, the costs of the targeted antimicrobials would have increased. Therefore, they estimated that the costs of targeted antimicrobials have decreased by a monthly average of £23,852 per month (95% CI: £18,154 to £29,549, *p<0.0001*).

1.10.6 Structural interventions

Structural interventions are not considered to be neither restrictive nor persuasive in nature. These interventions are considered as organisational interventions by EPOC *(see table 1.9)*. Seven studies reported on two types of structural interventions which were rapid antimicrobial susceptibility testing (n=3)[178-180] and rapid testing using polymerase chain reaction (PCR) (n=1)[181] . The effect of a computerised decision program for aminoglycoside dosing (n=2)[182;183] and as a guide for empirical therapy (n=1)[184] was also investigated. The intervention leads for these studies were undeclared. One CCT study (GRADE LOE (1^{+}/1^{-}) was conducted by Doern and his colleagues[178] and examined the impact of rapid antimicrobial susceptibility testing (RAST) on reducing the turnaround times for processing microbiological samples. The efficacy of RAST was compared to their overnight antimicrobial susceptibility testing (ONAST).They reported that RAST resulted in a significantly shorter time for the availability of susceptibility results [9.6h vs. 25.9h; *p<0.01*]. RAST and ONAST outcomes such as total LOS and LOS after a positive culture were compared and these outcomes were similar for both groups and were not statistically significant. For example, LOS after a positive culture was 14.7 vs. 14.6 day for RAST and ONAST groups respectively. However, mortality rates due to infection were significantly lower in the RAST group (7% vs. 12.7%; *p=0.023*). The mean antimicrobial expenditure was significantly lower in the RAST group ($1016 vs.

$1354; *p=0.0044*). Also, the overall costs per patient which included laboratory costs was significantly lower in the RAST group ($15,062 vs. $19,256; *p=0.0118*).

The use of computerised decision programs to improve antimicrobial prescribing was reported in three studies.[182-184] One RCT GRADE LOE (1^-) was conducted by Destache and colleagues[183] was conducted in a single tertiary hospital reported on the impact of a clinical pharmacokinetic service about dosing. However, the authors only reported outcomes from 74% of the control group and 68% of the randomised group. Consequently, these data lack internal validity and hence negatively impacted on the generalisability of these findings. One RCT GRADE LOE ($1^+/1^-$)[182] was conducted by Burton and colleagues, examined the impact of a Bayesian aminogylcoside dosing program on prescribing for patients receiving IV aminoglycosides. They reported that there was a significantly higher maximum peak concentration achieved in patients in the intervention group [5.3±1.8 mg/L vs. 4.4±1.7 mg/L; *p=0.001*]. Patients with pneumonia has a significantly lower LOS in the intervention group (11.8 days vs. 25.9days; *p=0.008*) and also the total LOS in the study was 4.3% (*p=0.028*) lower than in the control group. Additionally, there was also a trend towards a better response to therapy (86% vs. 73%) and lower nephrotoxicity (5.6% vs. 9.3%). These results should be interpreted with caution because there was lack of blinding of patients, physicians and investigators. The authors indicated that blinding of physicians and investigators was not possible because they need to adjust dosing using serum concentrations in both groups. Also, the study investigators were not blinded during data analyses. There was no measurement of baseline characteristics was not reported so therefore it was difficult to determine the validity of the effect sizes reported. Additionally, there was little control for contamination between study groups because study physicians switched between intervention arms every four months.

There were three RCT studies[185-187] found which investigated the effect of using novel biomarkers. Each study was categorised as GRADE LOE: $1^+/1^-$ which indicated these studies had a medium risk of bias. Franz et al (2004)[187] conducted a multi-centre RCT (GRADE LOE: $1^+/1^-$) in order to investigate the effect of a novel diagnostic algorithm for suspected bacterial infection in neonates. The diagnostic algorithm included the assessment of interleukin-8 (IL-8) and C-reactive protein

(CRP) and based their therapy on IL-8 > 73pg/mL or CRP >10mg/L. Study participants (n=1291) were eligible if they fulfilled the following criteria:

- at least one predefined clinical sign indicative of neonatal infection
- age < 72 hours
- clinically stability, able to wait for the results of diagnostic tests before the initiation of therapy

They reported that utilising biomarkers as part of the diagnostic pathway for bacterial infection was effective at reducing unnecessary antimicrobial prescribing without increasing the risk of missing patients with infection. For example, in the IL-8 group; fewer patients received antimicrobial therapy (36.1% vs. 49.6%; *p<0.0001*). Also, they found that IL-8 had a higher sensitivity (95% CI: 66% (58-73) vs. 59% (51-97)) if samples are analysed within the first12 hours of life. Based on their findings, they suggested that IL-8 and CRP should always be measured together in order to maximise their sensitivity. However, seven centres utilised CRP as part of their standard protocol which may have account for the results observed in this group. Also, the authors reported that the standard diagnostic protocol was not identical across the centres. The associated costs of the implementation of this intervention were not reported.

Christi-Crain and colleagues conducted two RCTs which examined the effect of procalcitonin-guided therapy for lower respiratory tract infections (LRTIs)[185] and CAP.[186] These studies were supplemented with persuasive interventions such as reminders and a written antimicrobial policy. Both studies reported that procalcitonin-guided therapy was effective at reducing antimicrobial use and antimicrobial costs. For example, Christi-Crain et al (2004)[185] reported that there was a 47% *(p<0.0001)* reduction in the proportion of patients for LRTIs. Christi-Crain et al (2006)[186] reported that the antimicrobial duration was reduced by 55% (median, 12 vs. 5d; *p< 0.001*) for patients with CAP. Similar to their 2004 study, they reported that this intervention resulted in the reduction of antimicrobial costs ($29,428 vs. $59,535; *p<0.001*) and the prescription of inappropriate antimicrobial therapy. The results from these studies should be interpreted with caution for example, in the 2006 study, due to the small sample size; the study had limited power to prove the safety of procalcitonin diagnostic pathway and the determination of the optimal therapy duration for CAP. Furthermore, the authors recommend that research is needed to investigate the efficacy of procalcitonin-guided therapy in outpatient settings.

The findings from these studies are discussed below in relation to each domain within ASAT v15a.

1.11 Domain 1: Antimicrobial management within the Trust

Domain 1 of the ASAT focuses on the responsibility of hospital trust boards in ensuring that AMS has a high prioritisation within their hospitals. This domain aims to examine the strategic approach of trust boards to AMS. The strategic approach could include the development of an overarching policy which clearly stipulates the processes hospitals should utilise in AMS. This policy should address AMS at a directorate-level, departmental-level, ward-level and relevant staff groups or teams. Also, it examines the involvement of infection control, drugs and therapeutics committees or equivalent committee in AMS. Chief executives and hospital trust boards are legally responsible for signing off compliance with the Health and Social Care Act (2008).[23] The development of an organisational culture which cascades down from the trust board to wards has been advocated by a number of reports.[20;188] There were two main types of AMS teams or equivalent identified in the literature. The first type of team or committee identified, reports directly to the hospital trust boards, Drugs and Therapeutics Committee (D&TC) or equivalent. Their remit is strategic and they tend to oversee the development and management of antimicrobial policies and guidelines. This committee is seen as the link between the trust board and other high-level committees within the trust such as the D&TC *(see figure 1.7)*.

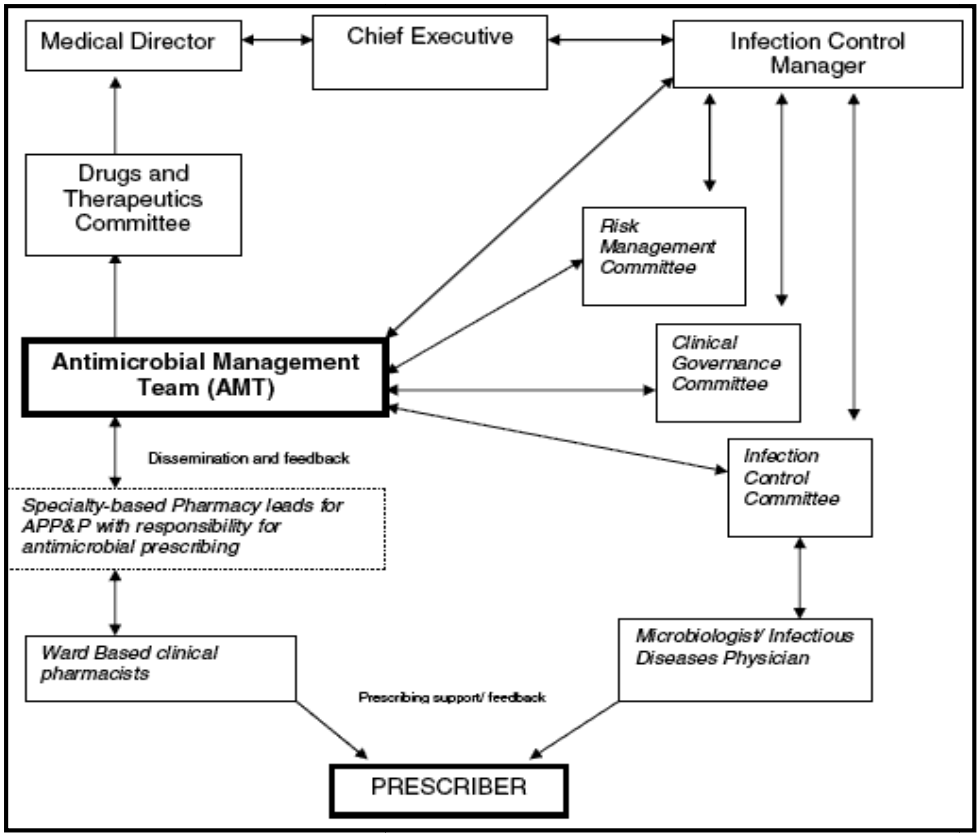

Figure 1.7 - The Model of Antimicrobial Prescribing Practice Pathway in Acute Hospitals[15]

Antimicrobial management-related guidelines have advocated that hospitals should form an antimicrobial stewardship committee or equivalent committee.[15;19] This committee should develop an antimicrobial stewardship strategy and are responsible for the implementation of the strategy.[19] The remit of this committee is to oversee the development of antimicrobial policies, guidelines and formularies, which should be done in response to available evidence and susceptibility data. This committee should endeavour to maintain good working relationships with their hospital's D&TC and trust board.[5;15] Additionally, this team should take responsibility in defining the core competencies for antimicrobial prescribers, which should be based on national standards. These guidelines recommend a multidisciplinary composition of the AMS committee.[15;19]

The hospital AMS committee should be composed of infectious disease clinicians, antimicrobial pharmacists, specialist pharmacists, clinical microbiologists, infection control nurses, senior management representative[15;19], epidemiologists[5] and an information technology specialist.[22] Some reports recommend that there should be *'link physicians'* on the wards in order to raise concerns about HCAIs such as CDI

and to establish AMS at ward level.[22] The evidence supporting the establishment of AMS committee was quite sparse. There were no high quality studies in the literature that investigated the impact of this intervention on ASPs. The evidence found investigated the impact of a *'ward-facing'* multidisciplinary team and will be discussed in *section 1.12*. However, as previously discussed in *section 1.4.4*, unintended outcomes of poor antimicrobial prescribing such as AMR should be one of main reasons for developing organisational level strategies for AMS. Domain 1 of ASAT v15.a has targeted these strategies so therefore there is rationale supporting the inclusion of this domain.

1.12 Domain 2: Operational delivery of the antimicrobial stewardship strategy

Domain 2 of ASAT v15a examines the control documents used to enforce AMS in hospitals such as antimicrobial policies, guidelines and formularies. The primary functions of clinical guidelines are to standardise patient care and to minimise variation in clinical practice.[189;190] Also, it is hypothesised that minimising the probability of medical errors could be possibly achieved by standardising clinical practice by using control documents such as guidelines.[191]

Antimicrobial guidelines provide advice or guidance about the drug(s) that should be prescribed for specific clinical conditions.[192] NHS trusts are expected to have treatment and surgical prophylaxis guidelines as recommended by the Specialist Antimicrobial Committee on Antimicrobial Resistance.[19] This sub-group produced a template for all antimicrobial guidelines for UK hospitals in May 2005. It is recommended that hospital antimicrobial guidelines are evidence-based.[19;24] These antimicrobial guidelines should be adapted local settings and should also consider AMR surveillance patterns.[24] Guidelines should be prepared to reflect the AGREE Enterprise recommendations for guideline production (www.agreetrust.org). The SACAR template stipulates that should contain the treatment regimens for common infections such as upper respiratory tract infections, lower respiratory tract infections, blood stream infections and soft tissue infections.

There were no RCTs which investigated this invention as the primary intervention. In *section 1.10.5.4*, there were nine ITS studies found which investigated this intervention. Each ITS study was categorised as GRADE LOE ($2^{+/}2^{-}$) which indicated that they had a medium risk of bias. Furthermore, this indicated that there

was a moderate to high risk that that the relationship between interventions and outcomes were not causal. The strength of evidence supporting the efficacy of guidelines in promoting AMS in hospitals was equivocal. Some studies demonstrated desired effects such as antimicrobial consumption and LOS. Other studies did not report sustained changes in outcomes for example one study did not report any significant change in LOS or antimicrobial costs.[168] Based on the evidence presented in *section 1.10.5.4,* it appears that guidelines are more effective when supplemented by other persuasive interventions such as education and audit with feedback. Implementation of control documents such as guidelines was the main focus of the interventions described in *section 1.10.4, section 1.10.5 and section 1.10.6.* Furthermore, the content of Domain 2 has been stipulated by guidelines, position statements and reports published by guideline producing bodies such as DH *(see table 1.1)*.

1.13 Domain 3: Risk assessment for antimicrobial chemotherapy

Implementation strategies for therapeutic drug monitoring (TDM) were structural in nature *(see section 1.10.6)*. These studies were categorised as GRADE LOE ($1^+/1^-$)[178;182], and GRADE LOE (1^-)[179;183] which indicated that these studies had a medium or high risk of bias respectively. There two studies[178;179] which examined the effect of antimicrobial susceptibility testing. One study GRADE LOE ($1^+/1^-$)[178], showed that RAST enabled the availability of microbiological data more rapidly and hence reduce laboratory costs but there was significant difference in LOS. The concealment of allocation was not done because study participants were randomised by their surnames. The other study GRADE LOE (1^-)[179] had a high risk of bias due the lack of protection from contamination between study groups. There two studies[182;183] which examined the effect of a computerised program for aminoglycoside dosing demonstrated. Burton and colleagues demonstrated that this intervention was effective at reducing outcomes such as LOS however there was a lack of blinding of patients, physicians and investigators. These interventions demonstrated a desired effect on outcomes however the results of these studies should be interpreted with caution due to limitations discussed in *section 1.10.6*.

1.14 Domain 4: Clinical Governance and audit/feedback strategies

Audit with feedback to prescribers was generally used as a reinforcement intervention to increase antimicrobial policy or guideline compliance[148] and was generally part of a multifaceted approach to implementing AMS. Although, there were 13 studies found which reported on this intervention *(see section 1.10.5.1)*. It was found that there were only two RCTs[136;141] which were categorised as GRADE LOE (1^+) which indicated that they had a low risk of bias. Therefore, causality could be assigned to the interventions under investigation. One RCT[136] which was conducted in a single hospital reported that audit with feedback was effective at reducing LOS and increasing compliance to guidelines by physicians. However, another RCT[141] which was conducted in 44 hospitals, reported that this intervention in conjunction with a QI initiative had limited efficacy in improving the timing of administration for surgical prophylaxis. Additionally, this RCT was conducted in parallel to a US national campaign on surgical prophylaxis.

The evidence supporting this intervention was equivocal however; it appears that local opinion leaders such as pharmacists and ID physicians were fundamental to the success of this intervention. Tailored feedback such as one to one feedback or direct counselling to prescribers by opinion leaders appears to have slighter greater efficacy than inter-organisational feedback as demonstrated by the Kritchevsky study.[141] There have been guidelines and position statements which recommend audit with feedback as part of hospitals' AMS strategies. However, more high quality studies are required to determine the effectiveness of this strategy in ASPs.

1.15 Domain 5: Education and training

The evidence underpinning this intervention has been presented in *see section 1.10.5.2.* There were 10 studies which reported on the effect of this intervention and most studies reported on mixed educational interventions such as didactic and focused interventions. Only four RCTs[155-157;159] reported on this intervention and each RCT was categorised as GRADE LOE ($1^+/1^-$) which indicated that they had a medium risk of bias. One RCT[159] was categorised as GRADE LOE (1^+) and was conducted in 25 UK hospitals. They found that educational outreach visits had a similar effect on antimicrobial prophylaxis in both control and study arms and this effect was not significant. This intervention appears to be most effective when used in conjunction with other interventions such as audit with feedback on individual

prescribing practice.[148-150] Also, the evidence suggests that educational interventions should be part of the strategy to improve antimicrobial prescribing and therefore should be included with ASAT v15a. As previously discussed in *section 1.10.5.2*, Cochrane reviews on educational interventions to change the behaviour of healthcare professionals indicated that further research is required to determine the efficacy of this intervention. [97;98;100]

1.16 Domain 6: Antimicrobial Pharmacist

In the literature, AMPs or clinical pharmacists with specialist training in infection management were reported as either:

a) a single intervention lead[123;127;129;133;134;138;139;158;161;169]
b) as part of a MDT[108;128;135;137;140;142;146;150;154;156;157;166;168;171;175]

However, it was difficult to determine whether they were more effective at implementing AMS solely or as part of a MDT from the included studies. This finding was similar to the Cochrane review[10] conducted in 2005 where they were unable to determine which intervention leads were most effective. The role of the AMP has been stipulated in guidelines and position documents and these publications indicated that AMPs should have a lead role in implementing hospital-based ASPs.[18;19;22]

1.17 Domain 7: Patients, Carers and the Public

Previous discussions have focused on interventions for implementing ASPs in hospitals. However, Domain 7 focuses on interventions to promote medication adherence in patients. These interventions have been the focus of 18 Cochrane systematic reviews which have focused mainly on disease-specific interventions. Ryan and her colleagues[193] conducted a review of systematic reviews (18 Cochrane and 19 non-Cochrane) which examined the effects of interventions that targeted healthcare consumers in order to provide evidence-based prescribing for, and also medicines adherence. They specifically looked at consumer-oriented interventions and based their review on the taxonomy of interventions for consumers' medication use which was proposed by Lowe et al (2010)[194] *(see table 1.14)*.

Table 1.14 -The taxonomy of interventions for consumers' medication use[194]

Category	Definition
Information and education	Strategies to enable consumers to know about their treatment and their health. Interventions include those to educate, provide information, or to promote health or treatment. Interventions can be provided to individuals or groups, in print or verbally, or face to face or remotely. Interventions may be simple, such as those seeking solely to educate or provide information; or complex, such as those to promote or manage health or treatment as part of a multifaceted strategy.
Support behaviour change	Strategies focussing on the adoption or promotion of health and treatment behaviours, such as adherence to medicines. Interventions may address behaviour change for the under-use, overuse or misuse of medicines, and may include practical strategies to assist consumers in taking their medicines correctly such as reminder devices, pre-packaging of multiple medicines, or different or simplified medicine formulations.
Acquiring skills and competencies	Strategies focussing on the acquisition of skills relevant to medicines use. Interventions aim to assist consumers to develop a broad set of competencies around medicines use and health, such as medicines management or monitoring; or training consumers in the correct use of treatments or devices to deliver treatment.
Facilitation and/or decision making	Strategies to involve consumers in decision making about medicines. Interventions include those that aim to help consumers make decisions about medicines use, such as interventions to encourage consumers to express their beliefs, values and preferences about treatments and care; and/or to optimise communication with consumers about medicines use and related issues.
Support	Strategies to provide assistance and encouragement to help consumers cope with and manage their health and related medicines use. Interventions can target patients or carers, as individuals or in groups, and may be delivered face to face or remotely.
Minimisation of risk and harm	Strategies specifically focussing on preventing or managing adverse events of treatment and complications of disease. Interventions can be for ongoing treatment or related to emergency or crisis events. Strategies aim to minimise risks or harms at an individual or at a population level, such as reducing use of antibiotics, or augmenting immunisation uptake.
Improving quality	Strategies to improve the total package, coordination or integration of care delivered. Interventions can involve substitution or expansion of one type of care, such as interventions that aim to overcome system barriers to medicines use, including access and financial barriers.
Consumer system participation	Strategies to involve consumers in decision making processes on medicines prescribing and use at a system level, such as in research planning, formulary and policy decisions. Interventions can involve consumers in different roles, such as planning, research, audit and review and governance.

The provision of education and information *(see table 1.14)* when used in combination with other interventions such as counselling had some evidence of effectiveness in improving medication adherence and clinical outcomes in patients. However, these interventions demonstrated variable effects in the included reviews. The effects of facilitating communication and/or decision making had mixed results.

They found that there was some evidence which supported interventions that did not have a focus of decision-making and/or communication which had variable efficacy on patient outcomes. For example, delayed prescribing was effective in decreasing antimicrobial use but it was found to have a negative effect on patient satisfaction. Also, delayed prescribing also had mixed effects on clinical outcomes and adverse events.

In terms of determining the effectiveness of structured counselling or compliance therapy, they found that there was insufficient evidence to support these interventions. Interventions to promote and facilitate the acquisition of *skills (see table 1.14)* and competencies of patients had a positive effect on adherence and clinical outcomes. Also, self-monitoring was found to decrease adverse drug events. The provision of training by pharmacists to improve adherence to therapy had limited evidence to support the use of this intervention. However, there was some evidence to suggest that it may improve the knowledge base of medicines.

Supporting behaviour change *(see table 1.14)* was found to be effective in simple interventions were used for short-term treatments and also in complex interventions for long-term treatments. Complex interventions were generally multifaceted in nature. Simplified dosing regimens were generally effective in improving medications adherence. Interventions such as reminders and education and those directly involving pharmacists were also reported as effective.

Providing support to patients *(see table 1.14)* was effective when utilised as a single interventions or in a bundle of interventions. However, there was limited evidence to determine which staff group should provide support and under which conditions support would be most efficacious.

Interventions to minimise risks or harm *(see table 1.14)* had mixed effectiveness in promoting adherence. It was concluded that educational strategies to minimise harm may be effective however informing patients about adverse events may negatively impact on adherence.

Interventions to improve quality of adherence were reported as effective for example changing the coordination of care had a positive impact on adherence. However, there were no reviews identified which determined the effects of consumer system participation *(see table 1.14)*.

Some of the most effective interventions appeared to be those which included pharmacists in medicines management. Other interventions such as reminders, and

education delivered together with self-management skills and training appeared to have inconsistent effects on adherence. Ryan and her colleagues found that that very few studies were conducted involving paediatric patients or their parents and/or carers. There was also a lack of evidence on interventions for patients on multiple medications for more than one concurrent health problem. They recommended that researchers need to address these gaps in evidence and also conduct studies with more robust methodologies such as RCTs.

Guidelines have been published by NICE which recommend interventions to promote medicines adherence in patients[195] and the key priorities for implementation (KPIs) are summarised in *table 1.15*.

Table 1.15- The key priorities for implementation for NICE clinical guideline 76 (Medicines Adherence)[195]

Number	Key priority for implementation
1	Healthcare professionals should adapt their consultation style to the needs of individual patients so that all patients have the opportunity to be involved in decisions about their medicines at the level they wish.
2	Establish the most effective way of communicating with each patient and, if necessary, consider ways of making information accessible and understandable (for example, using pictures, symbols, large print, different languages, an interpreter or a patient advocate).
3	Offer all patients the opportunity to be involved in making decisions about prescribed medicines. Establish what level of involvement in decision-making the patient would like
4	Be aware that increasing patient involvement may mean that the patient decides not to take or to stop taking a medicine. If in the healthcare professional's view this could have an adverse effect, then the information provided to the patient on risks and benefits and the patient's decision should be recorded
5	Accept that the patient has the right to decide not to take a medicine, even if you do not agree with the decision, as long as the patient has the capacity to make an informed decision and has been provided with the information needed to make such a decision
6	Be aware that patients' concerns about medicines, and whether they believe they need them, affect how and whether they take their prescribed medicines.
7	Offer patients information that is relevant to their condition, possible treatments and personal circumstances, and that is easy to understand and free from jargon
8	Recognise that non-adherence is common and that most patients are non-adherent sometimes. Routinely assess adherence in a non-judgemental way whenever you prescribe, dispense and review medicines.

Both published guidelines and the evidence indicates that the approach to medicines adherence should be patient-centred. For example, the second KPI *(see table 1.13)* stresses the need for healthcare professionals to ensure that medicine information is accessible and understandable by patients. This approach is necessary because patients are central to decision making and medicines management.[193] Generally,

patients decide whether they take medicines and how they will take medications. It has been reported that the factors affecting poor adherence is multi-factorial. The process of taking the correct dose, schedule and duration can be interrupted and this can lead to poor adherence.[196] It has been estimated that approximately 50% of patients do not adhere to prescriptions[197] and approximately 85% of patients are occasionally non-adherent.[198] Poor adherence has been associated with unintended outcomes such as adverse drug events, readmissions, AMR, treatment failure and death.[197;199]

The ASAT examines whether information about antimicrobials have been given to patients or their parents and/or guardians. The evidence base is equivocal and shows that interventions for medication adherence although they may have limited efficacy can still increase adherence. It is therefore necessary to include a section within the ASAT which examines the provision of medicine information because it should be part of built into good prescribing practice.

1.18 DISCUSSION

There were methodological issues and limitations associated with this literature review. Although, systematic reviews and RCTs are the highest quality of evidence,[94] there were very few high quality RCTs or CCTs (n=5) found in the literature which evaluated the impact of ASP-related interventions in promoting AMS. This is probably due to the ethical considerations relating to the control group, as it is unethical not to incorporate effective interventions of known efficacy into prescribing decisions.

ITS studies were the most commonly used study design (n=38) in the investigation of the effect of ASP-related interventions. However, this study design is limited due the time period required for data collection pre-intervention and post-intervention in order to prevent bias from external secular trends which are unrelated to the intervention(s) under investigation.[200] Most studies were conducted in a single centre settings so therefore it could have been difficult to obtain a sample which was adequately powered to detect statistically significant differences in outcomes such as clinical guideline adherence, LOS or in-hospital mortality.[201]

Originally, ASPs were designed to promote the judicious use of antimicrobials and to decrease antimicrobial expenditure. However, more recently, they have evolved into measuring the quality and appropriateness of antimicrobial use.[201] The evaluation of

hospital-based ASPs can be beneficial by identifying deficient areas of AMS hence highlighting targets for QI interventions and also by identifying which are the most effective interventions for hospitals.[201]

1.18.1 Process measures and outcome measures

It has been recommended that both process and outcome measures should be used in the evaluation of ASPs.[5] Dellit (2007), states that *'both process and outcome measures need to be defined and assessed when evaluating an ASP to confirm that goals of the intervention are attained and clinical objectives are met.'*[5]

Process measures are considered to be easy to measure and interpret. These measures can evaluate the quality of care but do not fully describe the clinical impact of interventions. Process measures can directly evaluate the quality of clinical care however there are only useful if there is causality between the process and the desired outcomes.[202] The appropriateness of antimicrobial use as recommended by guidelines as opposed to antimicrobial usage data is viewed as a more sensitive outcome measure of the effectiveness of ASPs.[201] This is because this process measure can assist in the determination of clinical outcomes and hence the efficacy of ASP-related interventions.

Outcome measures may not adequately evaluate the quality of clinical care. Typical outcome measures include clinical outcomes such as infection-related mortality, LOS, readmission rates, CDI rates and AMR rates however there are very few studies which use clinical response, success or failure as an outcome.[201] Clinical outcome is a composite endpoint which is subjective because it relies an investigator's assessment of patients which could be mainly based on experiential knowledge .[203] Clinical success is measured by clinical cure or clinical improvement rates and may be difficult to assign causality to ASP interventions even when outcomes have been adjusted for confounders and variability in the patient population.[201] Furthermore, measuring clinical outcomes over multiple time points does not necessarily improve the sensitivity of these outcomes.[204] Also, the timing of assessment of clinical outcomes is an important factor in determining the efficacy of interventions.[203] In other words, *'Is the time frame adequate to fully demonstrate the efficacy of outcomes?'* American Heart Association (AHA) states that *'When judging the quality of care provided by an individual or an institution, should the outcomes*

assessment be restricted to the initial hospitalisation only or should longer term assessments be included as well?

There have been arguments proposed for the inclusion of longer term (post-discharge) outcomes measures for example some interventions may have a positive effect on short-term outcomes however the full effect on patients may only be observed after discharge (days/weeks/months etc.)[205] Therefore, evaluation of longer term outcomes could potentially be incorporated into the study design of the evaluation or assessments of interventions. Clinical outcome data are considered to be the gold standard is the measurement or assessment of the efficacy of interventions in healthcare organisations, however there are limitations associated with using these data. However, these outcomes require an adequate timeframe in order to demonstrate the efficacy of interventions.[206]

Another limitation associated with clinical outcomes is that a large sample size is required to detect statistically significant effects on the study population.[202] Process measures such as guideline adherence tend to be more sensitive to the quality of care and are easily measured without significant bias or error there are subject to the interpretation of healthcare professionals involved in the care pathway of patients.[202;207] Furthermore, for mortality outcomes such as all-cause mortality, the determination of attributability can be subjective because they may be related to underlying comorbidities. As a consequence, they could be reported as a false positive, for example indicating that the antimicrobial treatment were related to the deaths.[203] Therefore, the interpretation of the results of studies which have utilised clinical outcomes should be done with caution because of confounders and the conditions under which the studies have been conducted.[201]

As previous mentioned, the assessment of interventions should include an evaluation of both process and outcomes measures as recommended by Dellit (2007) in order increase their validity and generalisabilty.[5] In this literature review, both process and outcome measures have been used alone or in conjunction in the determination of the effectiveness of ASPs. In addition, both types of measures have been used as either primary or secondary measures. The determination of the impact of ASPs can be complicated due to the multifaceted nature of ASPs. Furthermore, the evidence base supporting the effectiveness of interventions was limited due to the presence of potential confounders and study design limitations.[11;201]

The findings of this literature review support the argument that there should be an international harmonisation for reporting outcomes ASP-related interventions. Currently, there are standardised reporting guidelines for antimicrobial use such as the WHO Guidelines for ATC classification and DDD assignment.[208] However, there are no standardised definitions of outcomes such as clinical success or clinical failure. Recommendations have been suggested for the standardised reporting of methodological information in research publications on hospital antimicrobial use *(see table1.16)*.

Table 1.16: Recommendations for reporting methodological information in publications on hospital antimicrobial use[203]

Reporting methodological information in publications on hospital antimicrobial use	
1	Report hospital size, composition e.g. type of intensive care units, with or without bone marrow transplant or burn units etc. and also affiliation
2	Report mean length of stay, total number of bed days, number of patients admitted and numbers of admissions of individual patients to multiple hospital sites
3	Describe in detail the hospital wards that were included in the analysis, independently summarised all wards (including intensive care units), 'all intensive care units' and 'all wards' excluding intensive care units
4	Report DDD/100 bed days and DDD/100 admissions
5	Provide a clear definition of the term 'bed-day', count admission and discharge day together as 1 bed-day if possible
6	Report the version of the 'WHO guidelines for ATC classification and DDD assignment' that were used and use the most recent version at the time of publication
7	Select antimicrobials according to ATC classification. Include all drugs of ATC group 'J01' (antibiotics) and/or ATC group 'J' (antimicrobials)
8	For antibiotic use data in paediatrics, use days of therapy (DOTS) instead of DDDs, in possible

Nb. Antibiotics are all substances of ATC group 'J01' (antibiotics for systemic use). Antimicrobials are all substances of ATV group 'J' (anti-infectives for systemic use, including antibiotics for systemic use, antimycotics for systemic use, antimycobacterials, antivirals for systemic use, immune sera and immunoglobulins and vaccines). DDD (defined daily dose), ATC (anatomical therapeutic chemical classification index for antibiotics)

1.18.2 Causality between interventions and outcomes

Causality can be defined as a relationship between one phenomenon or event (A) and another event (B) in which A precedes and causes B. The direction of influence and the nature of effect may be observed empirically however causality or causal relationships maybe difficult to prove. Threats to external validity can be categorised in terms of causal relationships or causality with the parameters of a research study e.g. units, treatments, outcomes and settings *(see table 1.17)*.

Causal relationship over treatment variation *(see table 1.17)*

Causal relationship with units asks the question '*In which units does a cause-effect relationship hold?*' Study participants belong to the categories of individuals or organisations that are targeted by the study however participants are included in the study may systematically differ from those who are not included but who may fulfill the inclusion criteria. As a result, the cause-effect relationship observed in the included sample of participants may not be generalised to other similar units that are similar to the study participants.

Table 1.17: Experimental and Quasi-experimental designs for generalised causal interference showing the interaction with causal relationships[209]

Interaction with causal relationship	Description
Causal relationship with units	An effect found with certain kinds of units might not hold if other kinds of units have been studied
Causal relationship over treatment variation	An effect found with one treatment variation that might not hold with other variations of that treatment, or when that treatment is combined with other treatments, or when only part of that treatment is used.
Causal relationship with outcomes	An effect found on one kind of outcome observation may not hold if other observations were used.
Causal relationship with settings	An effect found in one kind if setting may not hold if other kinds of settings were to be used
Context-Dependent mediation	An explanatory mediator of a causal relationship in one context may not mediate in another context.

Causal relationship over treatment variation *(see table 1.17)*

The direction and size of an observed causal relationship varies over treatment variations. Consequently, the length of time of treatments or interventions should be carefully considered.

Causal relationship with outcomes *(see table 1.17)*

Causal relationship with outcomes asks the question *'can a cause-effect relationship be generalised over different outcomes?* Any intervention may have a positive or negative effect on outcomes, however there will be instances where little effect or no effect is observed on outcomes. Also, it is possible for an intervention to have different observed outcomes across study settings because each study setting may be systematically different.

Causal relationship with settings (*see table 1.17)*

Causal relationship with settings asks the question *'in which settings does a cause-effect relationship hold? Can researchers assume that their results can be generalised to other settings other than the study settings?* Large scale studies are required to address the causal relationships that would be observed in each study setting. Small scale studies may not be representative of the target population so therefore conclusions drawn from such studies may have limited generalisability.

Context-Dependent mediation (*see table 1.17)*

Context-dependent mediation is derived from the principle of the cause-effect or causal relationship between the intervention and the outcome. The mediation processes that occur between intervention and outcome are known as causal mediators or mediator variables (see *figure 1.7).*

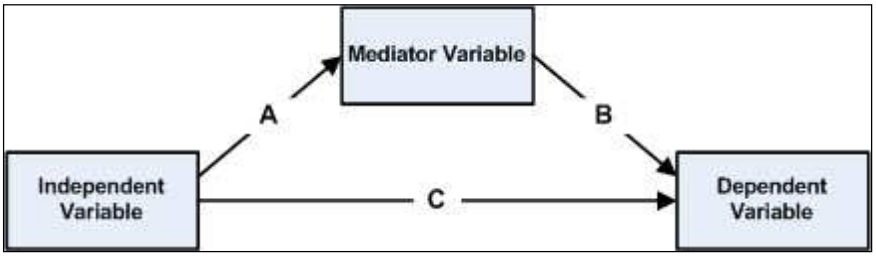

Figure 1.8- The relationship between an independent variable, a mediator variable and a dependent variable. The relationship between the independent variable and the dependent variable can be direct or indirect.[210]

Causal mediators or mediator variables are an essential component of the causal pathway; they possess the ability to transmit an effect of an independent variable to a dependent variable *(see figure 1.8).*[209;210] Causal mediation analysis facilitates the identification of intermediate variables (or mediators) that lie in the causal pathway between the treatment and the outcome. This type of analysis allows the researcher to explore causal pathways instead of simply estimating causal effects.[209;210] Causal effects occur when change(s) in one factor causes a change(s) in another factor. These effects can allow the researcher to determine whether a treatment has affected an outcome however causal effects cannot reveal '*why'* and '*how'* the effects have occurred. If a causal mediator is identified in one context, it does not necessarily indicate that the same variable may not mediate the effect in another context. Consequently, it is essential for the researcher to understand the difference

between a mediating variable or causal mediator and a confounder in order to understand the effects on the observed outcomes.

Establishing the cause-effect relationship between outcomes of AMS interventions such as LOS and re-admissions is more highly complex. The cause-effect relationship between persuasive interventions and outcomes is difficult to establish because these outcomes could have resulted from a number of internal or external confounders such as experiential knowledge. Likewise, the reduction in outcomes such as the incidence of HCAIs may be attributable other factors such as infection control procedures which threaten the internal validity and external validity of these studies. The causality between interventions and outcomes require closer scrutiny in order to confirm whether an observed outcome is directly attributable to an intervention. These outcomes are potentially multi-factorial and in some instances, may not be directly linked to antimicrobial consumption.

1.18.3 Other limitations

Detailed descriptions of the interventions or mode of their delivery were not generally available in the included studies so therefore it was difficult to conduct a comparative analysis between studies reporting similar categories of interventions. Authors used different terminology to describe interventions, for example, one author described *'review and change'* as an educational, persuasive intervention (academic outreach visits). However, EPOC describes educational interventions as workshops, seminars etc. targeted at healthcare professionals *(see table 1.9)*. This ambiguity of terminology was problematic in the comparison of interventions because authors used multiple terms to describe an intervention. Also, there was little or no description of pre-intervention prescribing rates and/or infection control measures in most studies.

As discussed in *section 1.16*, the assessment of which intervention lead delivered the most efficacious interventions was difficult to determine due to the differences in study design, intervention aims, and outcome measures. Some studies reported that support from a multidisciplinary antimicrobial committee was imperative to improving antimicrobial prescribing within their institutions.

Most studies, as expected, reported on the short term effect of interventions. The sustainability of interventions was not generally examined in studies and therefore it was difficult to evaluate the long term effects of interventions.

Furthermore, studies primarily focused on achieving prudent antimicrobial prescribing for expensive and problematic antimicrobials such as cephalosporins, aminoglycosides and glycopeptides. These antimicrobials are usually restricted in hospitals and are therefore subjected to strict control measures. Achieving prudent antimicrobial prescribing in unrestricted antimicrobials was generally not investigated in most studies. The authors may have assumed that the results of these interventions can be extrapolated to unrestricted antimicrobials.

Most studies were conducted on adult populations however there was a lack of studies conducted on geriatric, paediatric and neonatal populations.

A common limitation in research studies is the impact of the Hawthorne effect. The change in behaviour could be potentially due to the participation in research studies. In other words, *does the behaviour of prescribers alter when they are being observed?* The process of the assessment of prescriptions by other healthcare professionals may impact on prescribing decisions. However, if the control measure is removed, prescribers may not be as attentive to their prescribing decisions. Hawthorne effect may negatively impact on the generalisability of studies.

Generally, cost effectiveness analyses only reported on costs associated with the reduction of target antimicrobials usage. The costs associated with the implementation of interventions such as costs related to additional staff groups were not incorporated into the cost effective analyses. Some studies reported that there was a compensatory increase in the use of antimicrobials with similar spectrums of activity and such costs were also excluded from cost analyses. Therefore, it was possible that the costs associated with the implementation of ASPs may not have been accurately reported.

There were no standardised definitions of clinical infection or colonisation provided in the studies. The values of the minimum inhibitory concentration can vary between hospital laboratories locally, nationally and internationally.[211] ESCMID/EUCAST is currently undertaking a project for the harmonisation of MIC values across Europe.[212]

1.19 CONCLUSION

The ABS International project report stated that there is a need for further research into effective strategies for implementing ASPs.[38] They agreed with the findings of Davey and his colleagues who reported that the current evidence which supports the effectiveness of AMS is poor. Systematic reviews in this field are limited in terms of their generalisability to other healthcare settings. This was primarily due to the paucity of multi-centred studies, low quality of study design and a paucity of studies evaluating non-economic outcomes. Also, they suggested that there is a need to conduct studies which compare the effectiveness of single and multifaceted interventions on clinical and economic outcomes.[38]

This chapter presented the findings from the literature review on the organisational interventions for implementing effective ASPs in hospitals. Also, there was commentary on the relevant policies, guidelines and reports that pertain to hospital-based ASPs. The evidence presented in this chapter indicated that the seven domains of ASAT v15a examined the relevant interventions for implementing hospital-based ASPs. The results of the literature review highlighted that a number of studies were solely or jointly led by clinical microbiologists or clinicians that specialised in infection management. However, there was little coverage within ASAT v15a regarding the role and responsibilities of these staff groups in ASPs. The face validity of the ASAT has been previously tested by ARHAI[90] however there have been no investigations into the content or construct validity of the ASAT. The next chapter of this thesis provides a rationale for the methodological approach undertaken to investigate the content and construct validity of the ASAT and subsequently achieve the aims and objectives of this programme of work.

CHAPTER 2:

Programme of work

2. INTRODUCTION

Chapter 1 presented the findings of the literature review conducted prior to start of this programme of work. The relevant published guidelines and policies were mapped to the ASAT *(see section 1.3)* and it was clearly that each domain of the ASAT was underpinned by recommendations from these documents. Also, on analysis evidence base, it was deduced that ASAT v15a *(see section 1.5)* contained and measured the relevant and effective organisational interventions for implementing hospital-based ASPs. These findings of the literature review were also used to inform the direction of this research.

Chapter 2 presents the programme of work conducted to test the validity and subsequently improve ASAT v15a *(see section 1.5)*. Testing the validity of the ASAT prior to dissemination for use in hospitals is an essential phase in its development. A sequential exploratory strategy was undertaken *(see figure 2.1)*. The results of the several phases of validity testing were used to modify the ASAT in order to improve its validity. Ensuring the ASAT has validity was important because the results of an ASAT evaluation should be a credible reflection of actual practices. This chapter describes the aims and objectives of this programme of work and also provides the rationale supporting the methodological approach to evaluating the ASAT.

2.1 Aims, objectives and overview of this programme of work

2.1.1 Aims of this programme of work

The overall aims of this programme of work are to investigate the validity of the ASAT and to make iterative changes to improve its validity.

2.1.2 Objectives of this programme of work

The objectives of this programme of work are as follows:

- To investigate the content validity of ASAT v15a by conducting cognitive interviews with antimicrobial pharmacists (Study 1)
- To use the findings from Study 1 to modify ASAT v15a in order to produce ASAT v16 (Study 1)

- To investigate the content validity of ASAT v16 by conducting cognitive interviews and semi-structured interviews with clinical microbiologists (Study 2)
- To use the findings from Study 2 to modify ASAT v16 in order to produce ASAT v17 (Study 2)
- To collect quantitative data on participating hospitals' antimicrobial stewardship programmes using ASAT v17 (Study 3)
- To analyse each NHS trust's data using Rasch modelling and analysis in order to determine the validity of the ASAT v17 (Study 3)
- To modify ASAT v17 using the findings from Study 3 in order to produce ASAT v18 (Study 3)
- To determine whether the modifications such item reduction have improved the validity of the ASAT v18 using the same dataset and Fit statistics (Study 3)
- To conduct OLS regression modelling utilising NHS trusts *'ability'* estimates generated from the Rasch modelling and the CDI rates of participating NHS trusts in order to determine the ASAT's predictive validity (Study 4)

2.1.3 Methodological Approach

This programme of work is focused on validating and iteratively improving the ASAT. Investigations were conducted by the researcher in order to test the validity of the ASAT so therefore this chapter focuses on the concept of validity and how the methods undertaken in this programme of work has generated evidence for validity arguments. Prior to describing the sequential exploratory strategy utilised in this programme of work, a brief overview of validity is presented.

Validity can be defined as the extent to which a test claims to measure what it is intended to measure.[213] Validating a questionnaire or an instrument is a process where the degree or level of confidence that can be placed on the inferences that are made about the target population based on the scores from the measure.[214]

In terms of instrument development and construction, Gronlund (1990)[215] recommends that researchers consider the following premise: 'when constructing or selecting tests and other evaluation instruments, the most important question is, *'To what extent will the interpretation of the scores be appropriate, meaningful and useful for the intended application of the results?'* In addition, Gronlund (1990)[215] recommends when developing instruments, regardless of the type of instrument used or how the results obtained are to be used post-validation, that the instrument should possess validity, reliability and usability. The terms *'validity'* and *'reliability'* can often be confusing and sometimes used interchangeably.

It has been proposed that the concept of validity refers to the appropriateness of the interpretations made from the scores derived from the instrument under investigation and also that consideration is given to the context (setting) within which it has been designed.[215] If the instrument under investigation produces similar scores when the instrument is tested with the same study population, then the instrument is considered to have a high degree of reliability. Messick (1993) defines validity as '*an integrative evaluative judgement of the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of inferences based on test scores or other modes of assessment'*.

Gronlund (1990) has suggested that caution should be conducted when using the term *'validity'* as it relates to testing and evaluation of instruments. Firstly, as previously discussed, the term *'validity'* refers to the appropriateness of the interpretation of the results (or scores) of a test or evaluation instrument for population to which it has been administered and not the instrument itself. The interpretation of scores in context has been reinforced by Messick (1993).[216] He suggests that that only responses (or scores) generated from instruments have validities *(see table 2.1)* and reliabilities and not an instrument itself: *'…responses are a function of not only instruments, tasks, or stimulus conditions but of the subjects responding and the context (assessment or evaluation setting) of measurement*.' Secondly, Gronlund (1990)[215] suggests that researchers should consider validity as a matter of degree. In other words, validity should be described using categories that specify degree, such as high validity, moderate validity and low validity. Messick (1993)[216] also indicates that validity is a matter of degree, not a dichotomous all or none. Thirdly, Gronlund (1990)[215] suggests that researchers should note that validity is always specific to some particular use or interpretation.

He recommends that, when appraising or describing validity, researchers should consider the specific interpretation and how the results will be used. For instance, evaluation results will have a degree of validity for each interpretation or inference. Finally, Gronlund (1990) suggests that validity should be viewed as a unitary concept, which is based on different types of evidence such as content and construct validity. Traditionally, validity was categorised as discrete types *(see table 2.1)* which were not inter-related. Both Gronlund (1990)[215] and Messick (1993)[216] challenged this view of discrete types and they suggested that the validity sub-types are inter-related and not discrete entities.

Table 2.1: The definitions of sub-types of validity proposed by Gronlund (1990)[215] and Messick (1993)[216]

Type of validity	Gronlund (1990)[3]	Messick (1993)[4]
Content or content-related	The process of determining the extent to which a set of test tasks provides a relevant and representative sample of the domain of tasks about which interpretations of test scores are made.	The process of evaluating by showing how well the content of the test samples the class of situations or subject matter about which conclusions are to be drawn.
Criterion-related	The process of determining the extent to which test performance is related to some other valued measure of performance.	The process of evaluating by comparing the test scores with one or more external variables (criteria) considered to provide a direct measure of the characteristic or behaviour in question.
Predictive	-	The extent to which an individual's future level on the criterion is predicted from prior test performance.
Concurrent	-	The extent to which test scores estimate an individual's present standing on the criterion
Construct-related	The process of determining the extent to which test performance can be in terms of one or more psychological constructs	The process of what qualities a test measures, that is, by determining the degree to which certain explanatory concepts or constructs account for performance on the test.

Messick (1988)[217] proposed a unified approach to validity testing where each sub-type supports the overall concept of validity for an instrument. He states that *'the heart of the unified view of validity is that appropriateness, meaningfulness and usefulness of score-based inferences are inseparable and that the unifying force is*

empirically grounded construct interpretation'. Messick (1993)[216] describes construct validity as being based on an integration of any evidence that bears on the interpretation or meaning of test scores. Although, any evidence can contribute to construct validity, it can be strengthened '*if the degree of fit of the information with the theoretical rationale underlying score interpretation is explicitly evaluated'*. Construct validity, therefore, should be investigated in order to support the interpretation from the instrument scores.[218]

Consequently, based on these arguments, a unified approach to validity testing of the ASAT was undertaken in this programme of work. As previously discussed, the process of testing the validity of questionnaires ensures that there has been a robust methodology applied to the investigation of validity *(see section 2.1.6)*. The process of testing the validity of the ASAT gives us confidence about the inferences that could be made from ASAT scores.

Both qualitative and quantitative methodologies were undertaken in order to test the validity of the ASAT and hence achieve the aims and objectives of this programme of work. This approach was conducted in order to achieve an optimal data collection methodology for evaluation the ASAT. An optimal data collection method is defined as *'the best method, given the research question(s) and given certain restrictions'.* [219] Incorporating the use of both types of methodologies is known as a *'mixed methods'* approach. [220;221] This approach was chosen in order to compensate for any limitations due to utilising a unimode (single mode) approach.[221] The mixed methods approach utilised in this programme of work is known as the *'sequential exploratory strategy' (see figure 2.1).*[222] This strategy was conducted utilising a qualitative phase *i.e*. cognitive and semi-structured interviews (content validity testing) and then a quantitative phase *i.e*. Rasch modelling (construct validity testing) and simple OLS regression modelling (predictive validity testing) was conducted. In combination, these investigations were combined in order to investigate the validity of the ASAT, which were underpinned by the unified concept of validity.[217]

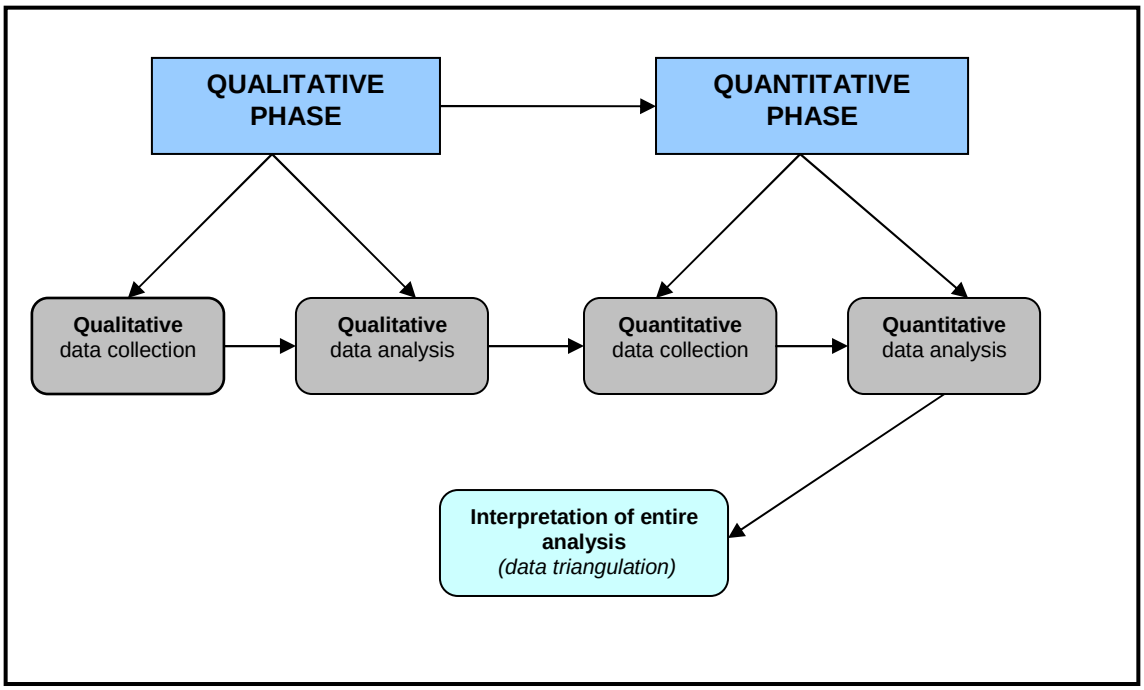

Figure 2.1 - The sequential exploratory strategy used in mixed methods research study design[222]

Data from both phases were triangulated to justify any modifications to the ASAT. It was hoped that this approach would provide optimal data which supported the modifications or revisions made to the ASAT.

2.1.4 Choice of methods

There are several methods that can be applied to the investigation of validity of questionnaires.[214;223] These methods can be either qualitative or quantitative in nature. As previously discussed, a sequential exploratory approach *(see section 2.1.3)* was used in order to achieve the aims and objectives of this programme of work. This approach incorporated both types of methods to the investigation of the validity of the ASAT. Study 1 was qualitative in nature and utilised cognitive interviews with AMPs in order to investigate of the content validity of ASAT v15a *(see section 2.2.10.2)*. Study 2 was also qualitative in nature and both cognitive interviews *(see section 2.3.10.1)* and semi-structured interviews *(see section 2.3.10.2)* with clinical microbiologists were used to investigate the validity of ASAT v16. Study 3 was quantitative in nature and utilised Rasch modelling and analysis *(see section 2.4.11)* in order to investigate the validity of ASAT v17. Study 4 was also quantitative in nature and utilised OLS regression modelling and analysis *(see section 2.5.11)* in order to investigate the validity of ASAT v18. One important aspect

of investigating the validity of questionnaires is that questionnaires should be tested in settings that are similar to the *'real settings'* in which they are likely to be completed.[224] Therefore, the researcher conducted in the interviews were conducted in the respondents' work areas in Study 1 and Study 2. Also, for Study 3 respondents were encouraged to complete the ASAT under normal working conditions and to collaborate with other staff where required *(see Appendix XXI)*.

2.1.5 Overview of the programme of work

This programme of work was conducted in four sequential studies (see figure 2.2). Each study was designed to generate evidence which would support any modifications to the ASAT.

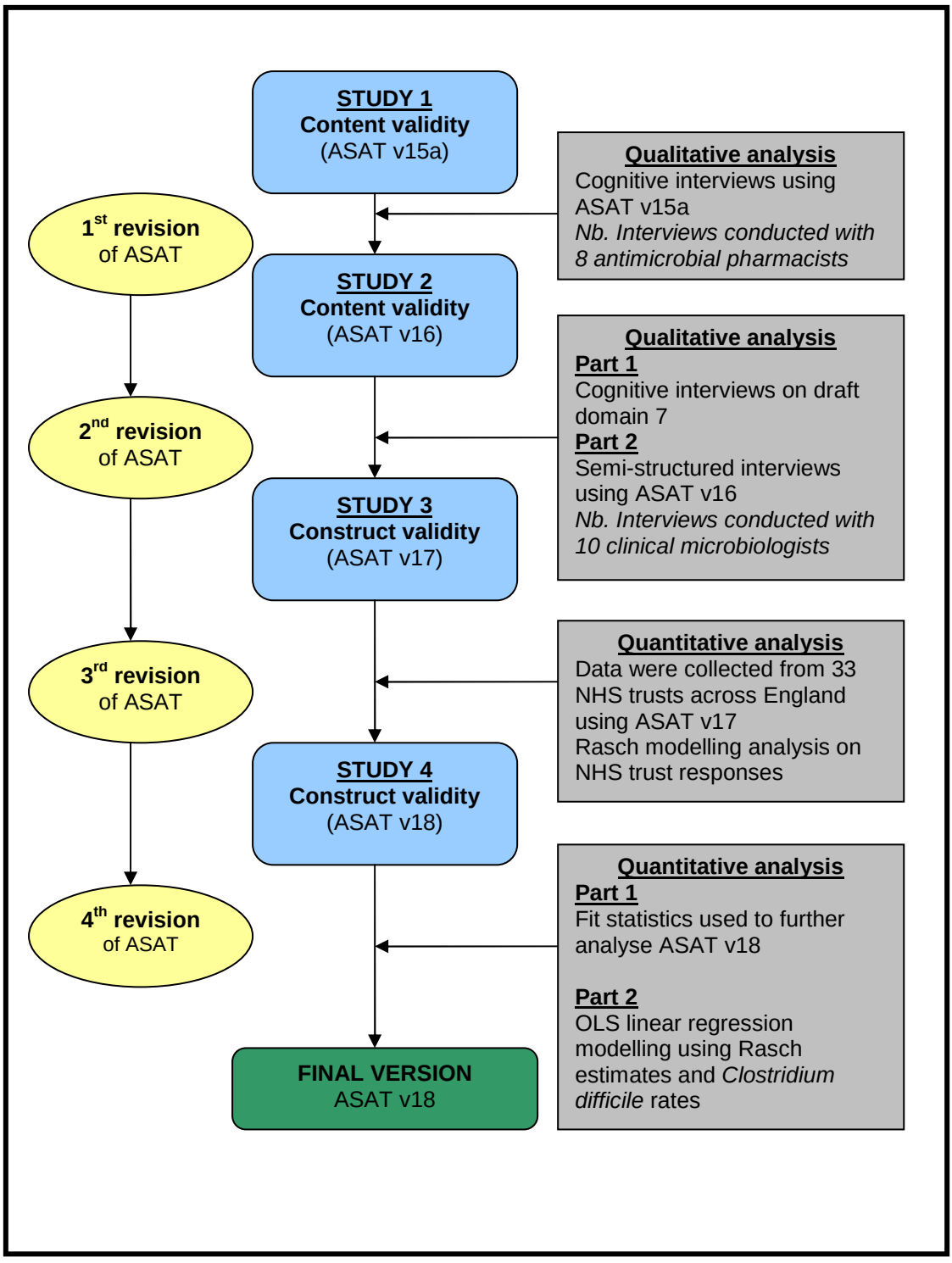

Figure 2.2 - The overall programme of work for the investigating the validity and improving the ASAT

2.1.6 Assessing the validity of questionnaires

There have been numerous proposed justifications for assessing the validity of questionnaires.[225] For example, it has been suggested that researchers need to give careful consideration to the respondent. The main premise underlying the use of

structured questionnaires in data collection is that both the questionnaire developers and the respondents or end-users share an identical frame of reference.[225-227] In other words, it is assumed that both groups of individuals will interpret words, phrases and responses using a similar approach.[226] During the process of testing the validity of questionnaires, there is a need to consider whether this statement is true, '*do all respondents interpret questions in the same way to which the questionnaire developers intended?'* Therefore, assessing validity, should involve an investigation of the respondents' (end-users) interpretation and questionnaire developer intent of each question and the questionnaire as a whole.

Construct validity can be considered as the integration of any evidence that bears on the interpretation of questionnaire scores, including content validity evidence.[217;228;229] Construct underrepresentation and construct irrelevance variance are threats to construct validity. [228;229] Construct underrepresentation occurs when the questionnaire is too narrow and fails to include important dimensions or facets of the construct. During item generation, it is possible to omit some features of the construct that should have been included which can limit the score meaning and interpretation. [230] On the contrary, construct irrelevance variance occur when the questionnaire is too broad. This can be a result of the presence of unrelated sub-dimensions or concepts present in the questionnaire, which are irrelevant to the construct. These unrelated sub-dimensions can introduce *'noise'* into the analyses. [228] In other words, unrelated sub-dimensions may be present in the measurement which can cause contamination. They can produce reliable variance in questionnaire scores but are irrelevant to the construct. Messick describes two types of construct irrelevance variance that can occur within instruments. Construct-irrelevant difficulty means the inclusion of tasks that are extraneous to the construct which makes the required task difficult for some individuals.

This can lead to construct scores that are invalidly low for affected hospitals. Construct-irrelevant easiness occurs when extraneous clues in the task permit some individuals to respond correctly or appropriately in ways irrelevant to the construct. The process of validation should be built into the instrument development pathway to ensure that the measurement tool would be useful enough in practice to make a meaningful assessment of the area under evaluation.[230]

In terms of investigating respondent-related problems, the researcher needed to select a method(s) that will answer the following questions; *do respondents*

understand the question or the task being asked of them? Do respondents understand the response options given in questionnaires? Does the respondent's interpretation correspond with what the question intends to measure? Does the respondent use different response categories or choices other than those offered in the question?[231]

Assessing the validity of questionnaires helps to collate data regarding respondents' interpretation of questions. These methods which use verbal reports from respondents are based on the following assumptions:

- respondents will verbalise every difficulty or barrier to response generation that they experience such as cognitive or non-cognitive difficulties
- every problem associated with the questionnaire will be identified through respondents' verbal reports , response accuracy
- questions where respondents do not verbally report any cognitive or non-cognitive difficulties may do not require any modifications[232]

These issues have been elucidated further by survey development methodologists to explain how they impact on measurement error.[233] A task-focused model has been proposed which focuses on the question and answer process *(see table 2.2)*.

Table 2.2 -The task-focused model and common examples of factors that may affect measurement error[233]

Task-focused model
Comprehension problems
Common examples: ▪ use of vocabulary ▪ complex sentence structure ▪ not understanding the nature of the task and the rules about how to respond
Validity problems
Common examples: ▪ respondents interpreting the same question in different ways ▪ respondents interpreting the same question in the same way but not as the researcher intended
Processing difficulties
▪ respondents may be unwilling or unable to retrieve the information necessary to answer the question

From the above discussions, it can be seen that there is a necessity for assessing the validity of questionnaires such as the ASAT. The rationale for the selected methods for testing the validity of the ASAT is discussed *(section 2.2 to section 2.5)*.

2.2 STUDY 1: The investigation of the content validity of ASAT v15a

As previously discussed, ASAT v15a was developed by ARHAI (*see section 1.5)*. The face validity has been previously tested[90] however there was no other assessment of validity conducted prior to the start of this programme of work. Study 1 investigated the content validity of the ASAT. Content validity ensures that the questionnaire possess item sampling adequacy.[234] In other words, it refers to the degree to which the items within a research instrument or measurement tool represent the universe of content for the concept being measured or the domain of a given behaviour.[235]

2.2.1 Aim

- To investigate the content validity of ASAT v.15a

2.2.2 Objectives

- To determine the content validity of the ASAT by acquiring *'think aloud'* data from antimicrobial pharmacists
- To modify and improve the ASAT using the findings from the cognitive interviews in order to produce ASAT v16

2.2.3 Methodological Justification

A number of alternative qualitative methods were considered by the researcher for assessing the content validity of ASAT v15a. These included focus groups *(see section 2.2.10.1)* and cognitive interviews *(see section 2.2.10.2).* Both these approaches are generally used to obtain verbal reports[232] from representative purposively selected respondents.[236] One of the most important assumptions of these methods is that verbal reports will provide high quality data about the problems that the respondent or participant encounter as they complete the questionnaire. Cognitive interviews was used as the data collection method in Study 1 as it provided comprehensive and in-depth data regarding the cognitive difficulties respondents encountered when completing the ASAT. These difficulties could be addressed and resolved in the next iteration of the ASAT.

2.2.4 Study sites

It is envisaged that the ASAT will be used in secondary and tertiary care hospitals to examine and quantify their ASPs. Participants were recruited from different types of trusts that exist in England such as acute and foundation trusts. Acute trusts manage hospitals and ensure that high quality services are delivered to patients.[237] Foundation trusts are run by local managers, staff and members of the public and have more financial and operational freedom than other NHS trusts.[237] Both types of trusts manage secondary and tertiary care hospitals. Ambulatory care and primary care settings were excluded because the ASAT was not formulated to address AMS in these healthcare settings. Recruitment into the main study was representative of trusts with diverse organisational characteristics. The Northwest Strategic Health Authority (SHA) was chosen because it is one of the largest SHA in England which consists of 29 hospitals and covers a population of 6,827,170.[238]

2.2.5 Sampling

Generally, most NHS trusts would have a 0.5 whole time equivalent (WTE) or a 1.0 WTE antimicrobial pharmacist in post. In instances where there is no antimicrobial pharmacist in post, a pharmacist would be assigned antimicrobial duties.

2.2.6 Inclusion criteria

Antimicrobial pharmacists were the main target group for the study. However, in instances where there was no dedicated antimicrobial pharmacist within the NHS trusts, pharmacists with antimicrobial duties were approached for recruitment into this study. Pharmacists with antimicrobial duties were defined as pharmacists who have the responsibility of AMS within their trusts or who have AMS part of their job description. It was essential that antimicrobial pharmacists with no previous exposure to the ASAT were included in this study. This was due to the nature of cognitive interviewing methodology where respondents should have no previous exposure to the questionnaire under investigation.

2.2.7 Exclusion criteria

Pharmacists who do not have AMS included within their job description or not involved in AMS were excluded from Study 1. AMPs were given the opportunity to

decline participation in the study. In instances where they indicated that they did not wish to take part in the study, they were also excluded.

2.2.8 Recruitment of participants

Participants were recruited from North West Antibiotic Prescribing Group (NWAPG) which is a professional network of antimicrobial pharmacists in the northwest of England. The NWAPG had an active membership of 43 antimicrobial pharmacists at the time of study recruitment. The strategy used to recruit participants for Study 1 is shown in *figure 2.3*.

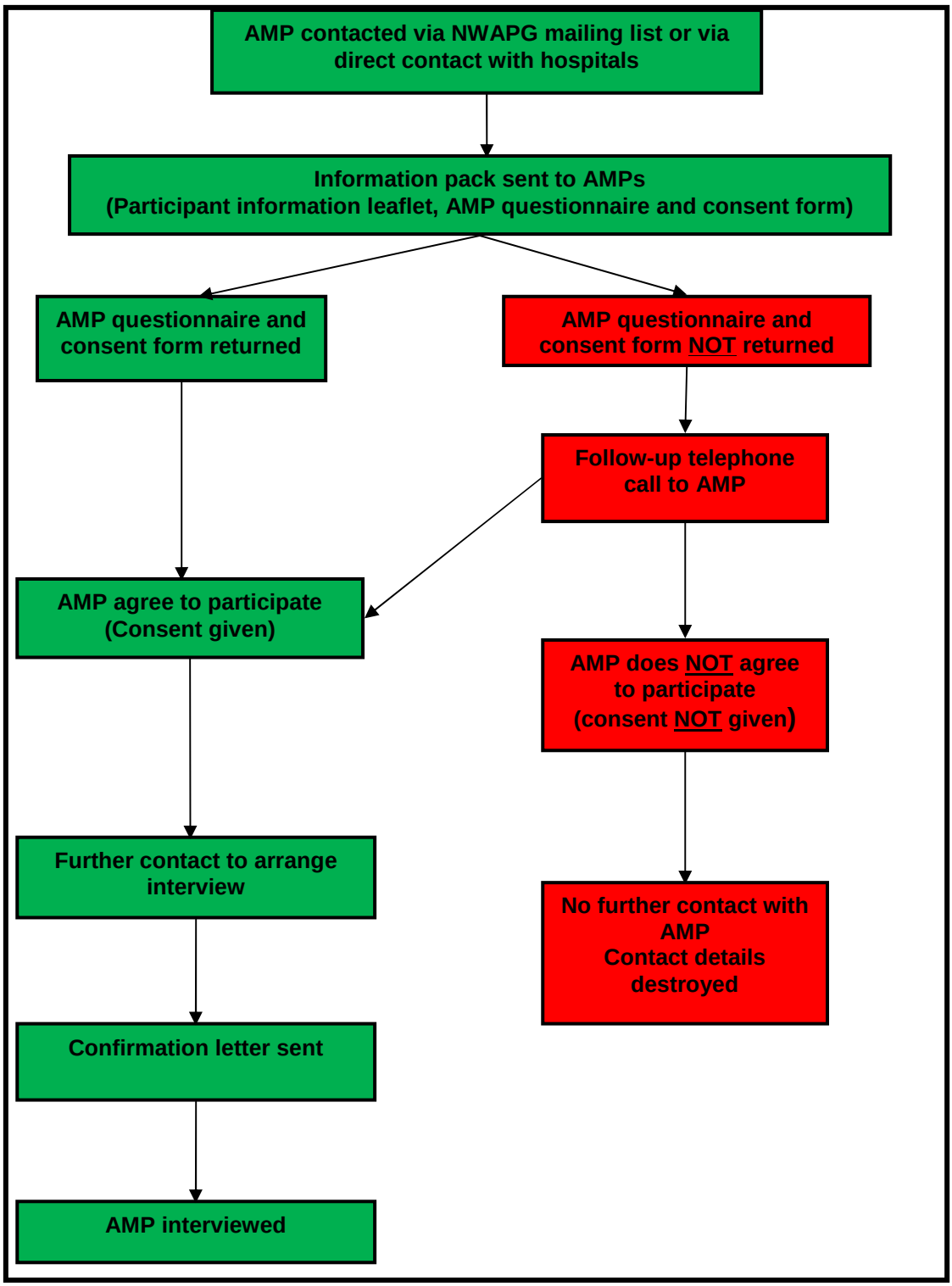

Figure 2.3 - The recruitment strategy used in Study 1 for antimicrobial pharmacists AMP(s)

An information pack which included a letter of invitation, participant information leaflet, and participant questionnaire *(see Appendix III, IV, and V respectively)* was sent to each member of NWAPG. The letter of invitation stated that antimicrobial pharmacists who were willing to take part in the research study should contact the

researcher either by the telephone or email to arrange a convenient time and location to conduct the cognitive interview. The participant information leaflet provided potential participants with further details about the research study. One of the main aims of cognitive interviews was to obtain *'first hand'* data from the respondents while completing the ASAT. Previous exposure would contaminate the data collected from the interviews so pharmacists were not given access to the ASAT until the interview had started. Therefore, it stated in the participant information leaflet that participants who had previous exposure to the ASAT could not participate in the study.

If an antimicrobial pharmacist indicated that they were willing to participate in the study then they were asked to return the participant questionnaire by email or post (where applicable) to the researcher. Once the participant questionnaire was received further contact was made with the participant in order to arrange a convenient time and location for the cognitive interview. After a suitable time and location for the cognitive interview was arranged, a confirmation letter *(Appendix VI)* was sent to the participant. This confirmation letter contained the agreed time and location for the cognitive interview. Also, a consent form *(Appendix VII)* was sent to the participant before the interview. The consent forms were collected prior to the start of the interview. This form allowed each participant an opportunity to decline from further participation in the study. After each interview every participant was sent a thank you letter by the researcher *(Appendix VIII)*.

2.2.9 Sample size

Willis (1999) have developed well-established techniques for conducting cognitive interviews.[239] He recommended that five to ten participants should be interviewed for each round of cognitive interview testing. A purposive sample[236] of eight AMPs were interviewed during this round of assessing the validity of the ASAT.

2.2.10 Methods

This section specifically provides the rationale for using cognitive interviews for collecting data from AMPs and using a thematic framework for data analysis.

2.2.10.1 Focus groups

Focus groups are generally used by researchers in the very early stages of questionnaire development.[231;240] Focus groups are usually composed of 10 to 15 participants that are typical of the target sample. This method can be used to elucidate issues that are essentially cognitive[240], so therefore they have similarities with cognitive interviews. They are aimed at evaluating and examining the respondents' understanding of key terms and concepts, information recall and retrieval mechanisms such as estimation strategies, and the frame of reference or interpretation used by respondents in the draft version of the questionnaire .[231;240] Focus groups can be used to obtain a general assessment of the respondents' ability to complete the questionnaire (response saliency) and generate ideas about rewording questions if required.

One of the main advantages of focus groups is that the members can use commentaries from others to help stimulate and formulate ideas.[231] Observation of the focus group participants' behaviour can provide the researcher with valuable insights on the potential questionnaire revisions required. However, Cosenza and Fowler (2000) suggests that focus groups may not be the best method for examining detailed aspects of the questionnaire such as question wording.[241] Focus groups can be useful in identifying overarching problematic themes with a questionnaire but not the underlying causes or triggers.[240;242] Cognitive interviewing can provide more in-depth data than focus groups regarding an individual participant's perception of a quesionnaire.[242] Questionnaires such the ASAT, which are composed of a larger number of questions, require a more in-depth approach for analysis. Due to the limitations discussed above, focus groups were deemed inappropriate for pre-testing the ASAT as this method was more suited to questionnaires with 5 to 10 items. Therefore, cognitive interviews *(see section 2.2.10.2)* were used to investigate the validity of ASAT v15a.

2.2.10.2 Cognitive interviews

Cognitive interviewing was the chosen method for investigating the validity of ASAT 15a and were conducted until category saturation was attained.[243] In other words, interviews were conducted until relatively few new insights were generated. Cognitive interviewing is a diagnostic tool for pre-testing survey instruments such as questionnaires which have been developed out of systematic collaboration between

cognitive scientists and survey researchers.[225;244] Cognitive interviews are a type of in-depth interviewing which focuses on the mental or cognitive (non-verbal) processes that respondents use to answer survey questions. Cognitive interviews can help to reveal how respondents understand an item on questionnaires and the reasons underlying the given response. This method can elucidate and identify the response stage at which a problem has occurred therefore the researcher is able to modify questions to address identified problems.[244] However, distinction should be made between this type of interview and another type of cognitive interview which was used as a memory aid for crime witnesses .[245]
Cognitive interviews provided valuable information on the access to content, comprehension or incomprehension of the content and constructs and also the interaction between respondent's characteristics and the questionnaire items. Construct irrelevance and underrepresentation of items can be introduced into the questionnaire if the cognitive processing theory is not applied to instrument development.[229] Consequently, without the application of cognitive testing into the development of the ASAT, there is potential that it could measure sources of variance that are not related to the intended questionnaire content. Therefore, ASAT would contain construct irrelevant factors that would consequently interfere with the respondent's ability to demonstrate their knowledge of a NHS trust's AMS practices. Subsequently, the ASAT results could be an underestimation or an overestimation of a hospital's performance. Therefore, cognitive interviews could be a very useful and informative stage in the development of an instrument because it provides insight into the respondent's cognitive processes as they complete the instrument.

Verbal probing can be used as an alternative to the *'think aloud'* technique.[239] However, for the purpose of this study, probing was used as a method which complimented the *'think aloud'* method. This technique was used to further explore the verbal reports provided by respondents. Both pre-prepared and concurrent probes were used in the cognitive interviews *(see table 2.3)*. Pre-prepared probes were developed in advance of the cognitive interview as part of the probe sheet *(see Appendix IX)*. Concurrent (spontaneous) probes were developed instantly in order to follow up on the responses from the participant.

Table 2.3 - List of common verbal probes used in cognitive interviews[242]

Cognitive probe	Example
Comprehension/Interpretation probe	What does the term '_____' means to you?
Paraphrasing	Can you repeat the question I asked in your own words?
Recall probe	How do you remember '_____'?
General probes	How did you arrive at that answer? Was that easy or hard to answer? I noticed that you hesitated. Tell me what you were thinking.

Pre-prepared and spontaneous prompts were used to guide the interview process *(Appendix IV-interview protocol)*; however the researcher ensured that the interviews remained respondent-led by only probing respondents after they had finished speaking. This is recommended as probing should be conducted when respondents' are able to remember the rationale behind their responses. Cognitive interviews and verbal probes were used to collate data on any difficulties experienced along the cognitive processing pathways *(see section 2.2.10.3)*.

An evaluation of usability of the ASAT was conducted as well as part of the validity testing of the ASAT. Data were obtained from cognitive interviews regarding the relevance of the ASAT domains, questions, scales and ASAT format/layout, text/language and overall design for example, intuitive flow of questions within each domain *(see Appendix IX-interview protocol)*. Cognitive interviewing also provided information on the respondent's views about the length of the ASAT, ASAT layout, ease of use, any domain and/or question omissions, relevance of domains and/or questions, overall instrument design and also overall satisfaction with the ASAT.

2.2.10.3 Cognitive processing pathways

Respondents employ cognitive processes when formulating or generating responses to questions contained within surveys and questionnaires. These processes include comprehension or interpretation, recall or information retrieval and judgement, all of which subsequently informs the response(s) generated by respondents. Several models have been proposed to describe how respondents process information in order to generate a response to a survey or questionnaire item.[246] These models propose that there are fundamentally four cognitive steps which respondents undergo in response generation. These steps are as follows:

- Comprehension/interpretation or Question encoding

- Information retrieval from memory
- Decision and Judgment (Heuristics)
- Response formatting or generation

Generally, response generation does not occur in coordinated, sequential steps but instead respondents may return to each step in order to generate a response. However, conceptually researchers have classified survey response or interaction theory into these four discrete steps in order to describe the survey interaction process. These steps are commonly viewed to underpin the interaction of the respondent with the questionnaire during response generation. However, it should be noted that these steps are interdependent processes because preceding steps will inform subsequent stages of response generation (and *vice versa*). The resultant response is therefore produced from the respondents' analysis and interpretation of the question utilising these four steps.

2.2.10.3.1 Comprehension and interpretative processes

The comprehension or interpretation of questions is a principal issue when examining the survey interaction process. There must be adequate input from this phase to inform subsequent phases of cognitive processing.[244] The comprehension or interpretation of the question will produce an internal representation of what the question is asking which will inform subsequent cognitive processes.[247] Willis (1991) describes this internal representation as *'an internal representation of the survey question that serves as a signal that an output of information is requested'.*[248] This internal representation will be formed via a two-step approach.[249;250] Conrad (1996) summarises this two-step approach as follows:

'Understanding a question involves both determining what information is being requested (a literal interpretation of the question) and recognising an unstated directive about how that information is to be provided (what procedure the respondent is to use in order to satisfy the request'.[244]

This two-step approach involves the identification of words, the recall of lexical information from semantic memory and the eventual construction of the question meaning.[244;249] Analyses of this phase of the survey interaction process provide questionnaire developers with data on whether the respondents' interpretation of each question maps to the developers' intended question objectives.[249] Verbal reports produced by respondents can provide evidence of any cognitive difficulties

they have experienced during this phase of response generation or formatting. Common problems associated with question comprehension are derived from respondents' lack of comprehension of question content. Also, these problems are due to lexical and structural ambiguities such as incorrect or complex syntax[251;252], unfamiliar technical terms and vague and imprecise terms.[251]

2.2.10.3.2 Memory or recall processes (Information retrieval)

Respondents will use recall strategies which have been triggered from the results comprehension or question encoding steps.[249] The main types of recall strategies which respondents use include estimation or actual counts. During this phase of cognitive processing, the information required to answer the question is retrieved from memory. Recallabilty of information can be defined as the types of information the respondent needs to recall in order to answer the question such as frequency estimates.[253] Both factual information retrieval requires a multi-step process, respondents are required to remember what events occurred, when events occurred and/or potentially use estimating and reconstructing strategies for response generation.[253] Estimation and reconstruction strategies may involve inference, which is used by respondents to fill in partial memories. Recall strategies can be direct or indirect. Direct recall strategies are used when the respondent is able to recall information that completely answers the question. Indirect recall strategies involve using an estimation heuristic based on recalling partial or inadequate information.[248] These strategies are used to produce the raw data used on which the generated response is based.

Questions that examine event frequency require respondents to use the recall strategies as previously discussed. However, from the perspective of the researcher, it is hoped the respondents will employ an episodic enumeration strategy as opposed to episodic estimation strategy.[254] Recalling every relevant event (episodic enumeration) will lead responses with higher response accuracy. Information retrieval processes can be hindered by the following reasons:

- an item may be irretrievable because the recall context is different to the encoding context
- an item may be difficult to distinguish from similar events or information
- an item maybe tainted with interference or contamination from a similar event[225;255]

It is necessary to consider the strategies used by respondents during this step of the survey interaction process in questionnaire development. If the question requires a significant amount of respondent burden it may be an indication that question modifications are required.

2.2.10.3.3 Decision and judgment (heuristics) processes

Judgement is a very important step in the survey interaction process because it can influence response accuracy.[242] This stage is commonly viewed as the point at which respondents formulate responses to the survey question.[225] It is thought that these processes are the *'control processes'* which guide the search and output of information. Response bias or response distortions can be introduced at this stage of cognitive processing. The respondent's selected response may be affected by both response styles and response sets.[256] Response styles can be defined as the respondent's bias to respond in a particular direction regardless of the content of the test items. Common examples of response styles are acquiescence, extreme tendency responding and central tendency responding and negative affectivity bias. Response sets can be affected by the content of the questionnaire and describes the respondents' conscious or unconscious attempt to create a particular impression for example social desirability responding *(see table 2.4)*.

Table 2.4- Common response styles and response sets[256]

Response styles	
Acquiescence response style	Refers to a tendency to respond positively e.g. 'true' or 'yes' regardless of the content of the question. *Agreement acquiescence* is defined as the tendency to agree with all items. *Acceptance acquiescence* is defined as the tendency to endorse all statements even if there are contradictory.
Extreme and moderacy response styles	Refers to the tendency to consistently using particular sections of a rating scale. Demographic factors of respondents can affect both types of response styles.
Response sets	
Social desirability	Refers to a tendency to answer items in such a way to consciously or unconsciously represent oneself in a particular way also known as *self-deception*. *Impression management* can be defined as claiming to perform desirable behaviours or not performing undesirable behaviours.

2.2.10.3.4 Response processes (response generation)

Response processing is also known as response mapping. Respondents must translate the judgments reached about the question that is being asked into a response.[247;248] This is the reverse of the question comprehension or encoding process because respondents have to recode the question answer into a written format. In other words, respondents produce an output from an internally coded form of the information that will be reported.[248] Respondents therefore produce a response that is informed by the previous stages in cognitive information processing and map their response(s) to the most appropriate option(s).

It has been proposed by Tourangeau and his colleagues that the process of response generation is undertaken by respondents in two phases.[257] Firstly, they propose that respondents will map their answers to the given response options in each question, also known as *'response mapping'*. However, this is only applicable to forced choice questions. The second phase of response generation is called *'response editing'.* It has been argued that response editing phase occurs during the decision/judgement phase *(see section 2.2.10.4.3)* of some survey interaction models. The models of information or cognitive processing will be discussed in a later section of this chapter *(see section 2.2.10.5)*. These models have been created to map the respondents' interaction with the questionnaire to the four core stages of response generation.

Table 2.5 -The types of problems associated with interpreting questionnaires[244;258]

Problem classes	Definition
Lexical	Refers to respondents not knowing the meaning of words or how to use them. Meaning refers to the *'core'* or *'central'* meaning of words or phrases.
Inclusion/exclusion	Refers to whether certain concepts should be considered within the scope of the question or the words or phrases.
Temporal	Refers to problems that that involve the time period to which the question applies.
Logical	Refers to a range of problems that involve logical connectives such as *'and'* and *'or'*. The presence of false presuppositions that are not applicable to the target group, contradictions and tautologies are examples of logical problems.
Computational	Refers to respondents' difficulty processing and manipulating information e.g. difficult mental arithmetic.

The theoretical basis of cognitive processing pathways assumes that each respondent will verbally express every cognitive difficulty they experience from encoding the question to response formatting or response mapping. Other problems types such as lexical, inclusion/exclusion, temporal, logical, temporal and computational problems have been included in the analysis and are described below *(see table 2.5)*. The thematic framework used by the researcher to analyse the cognitive data was based on the four main phases of cognitive information processing *(see section 2.2.10.4.1 to 2.2.10.4.4).*

2.2.10.4 Data collection

Qualitative data were obtained from respondents using cognitive interviews Cognitive interviews were conducted with eight antimicrobial pharmacists in the Northwest SHA using ASAT v15a. Pre-prepared and spontaneous probes *(see section 2.2.10.2)* were used to guide the interview process; however the interviews remained respondent led (*see Appendix XI* - Interview schedule).

2.2.10.5 Qualitative data analysis

Qualitative data analysis was conducted on the transcribed cognitive interviews using a thematic framework based on the Four-Stage model *(see section 2.2.10.5.1)* and the Flexible Processing Model for survey interaction *(see section 2.2.10.5.2)*.

Cognitive processing models have been devised to explain the order of the cognitive processing pathways *(see section 2.2.10.3)* used by respondents in generating responses to questionnaires/surveys. Seven cognitive processing models have been proposed to describe how respondents process information in order to respond to a survey or questionnaire item.[246]

Collectively, these models are known as survey respondent models or information processing models and they aim to classify each cognitive process into the correct order of cognitive assessment by respondents. Two models have been proposed to describe the interaction with opinion or attitude surveys[257] and behavioural frequency surveys.[259] However, these were not applicable for analysis the data from Study 1 because the ASAT is not an survey that measures opinions or attitudes. Other models have been proposed to describe the interaction between the respondent and the interviewer in unstructured and semi-structured interviews.[260;261] The Form

Appraisal Model suggests a standardised questionnaire appraisal form to critically evaluate the technical aspects of the questionnaire.[247] However, this method of analysis is not conducted on verbal reports so therefore it was not used for the analysis of the responses from the ASAT. Conrad (1996) suggests that cognitive interview responses should be modelled on the Respondents Question-Answer model.[244;262] This model has been simplified by Tourangeau and his colleagues in 1984 however the basic phases of the cognitive processing pathway are similar.[255] They propose that these phases are sequential and discrete. This theory has been challenged by Willis and his colleagues who propose that cognitive processing is not sequential and respondents may revisit prior phases before formatting a response.[248]

2.2.10.5.1 Four-Stage model

As previously mentioned, the Four-Stage model was developed by Tourangeau and his colleagues in 1984.[255] It proposes a four stage approach to response generation as opposed to the Respondent Question-Answer model which proposes a five stage approach. Tourangeau's model suggests that the following discrete, cognitive stages are undertaken by respondents

- comprehension
- information retrieval
- decision/judgement
- response generation

Tourangeau proposes that these stages are sequential however it has been shown that respondents may revisit preceding stages for response generation.[246] This model of survey response is one of the most accepted models in survey research methodology.[263] The Four-Stage model was to analyse the verbal reports in instances where respondents did not appear to revisit previous stages in the cognitive processing pathway.

2.2.10.5.2 Flexible Processing model

This model proposes that respondents undergo judgement/decision processes at more than one point along the cognitive processing pathway. Willis and his colleagues proposed that judgement/decision processes occur before and after the information retrieval stage.[248] These decision processes that occur prior to information retrieval can include the practicality of searching memory for the required

information. Alternatively, after the information retrieval stage, respondents may determine the accuracy of the information retrieved prior to response generation. In instances where the information retrieved has been deemed insufficient or unsuitable for response generation, respondents may undertake further judgement/decision processing. Therefore, this model also proposes that there is not sequential cognitive processing as with other models.

Each cognitive process is dependent on the preceding or subsequent processes in order for respondents to generate a response to a questionnaire item. Therefore, analysis of the verbal reports were conducted utilising the cognitive processing phases as previously described. In instances where respondents appear to revisit previous stages this model was used for data analysis for example rereading questions.

2.2.10.6 Thematic Framework or Framework Charting

Each cognitive interview was digitally recorded and transcribed verbatim. Data analysis was conducted on the transcribed interviews using a thematic framework approach[236;264] based on the Four-Stage model *(see section 2.2.10.4.1)* and also the flexible processing model *(see section 2.2.10.4.2)*. Qualitative data analysis software such as NVivo was not used to facilitate data analysis by the researcher. Instead, the transcribed interviews were entered into an Excel spreadsheet as an alternative to using data analysis software *(see figure 2.4)*. This was done because there were less than 10 interviews conducted in this study and the data analysis could be done manually due to this sample size.

Domain 1	INT1	INT2	INT3	INT4	INT5	INT6	INT7	INT8
1.1								
1.2								
1.3								
1.4								
1.5								
1.6								
1.7								
1.8								

Figure 2.4 - The template used for entering the transcribed interviews (Domain 1)

The Excel spreadsheet allowed ease of coding and analysis of the data. The responses to each question were entered in adjacent columns so that direct comparison between respondents could be facilitated. In total, 664 data fields were analysed by the researcher. The process of data synthesis had to be robust to ensure the validity (data interpretation) of the data.

Thematic framework or Framework Charting *(see table 2.6)* provides a systematic, comprehensive and step-wise approach to data analysis.[264] This method was chosen because it has been specifically designed to enable transparency of data analysis and allows for *a priori* and emergent concepts to be analysed.[236;264] This type of analysis involves five main stages which are familiarisation *(section 2.2.10.5.1)*, identifying a thematic framework *(section 2.2.10.5.2)*, indexing *(section 2.2.10.5.3)*, charting *(section 2.2.10.5.4)*, and also mapping and interpretation *(section 2.2.10.5.5)*.

Table 2.6 - The stages of Framework Charting (Qualitative data analysis)[236]

STAGE	DESCRIPTION
Familiarisation	This stage of qualitative data analysis involves immersion in the raw data *(or typically a pragmatic selection from the data)* by listening to tapes, reading transcripts, studying notes and so on, in order to list key ideas and recurrent themes.
Identification of the thematic framework	This stage of data analysis involves identifying all the key issues, concepts, and themes by which the data can be examined and referenced. This is carried out by drawing on *a priori* issues and questions derived from the aims and objectives of the study as well as issues raised by the respondents themselves and views or experiences that recur in the data. The end product of this stage is a detailed index of the data, which labels the data into manageable chunks for subsequent retrieval and exploration.
Indexing	Applying the thematic framework or index systematically to all the data in textual form by annotating the transcripts with numerical codes from the index. This is usually supported by short text descriptors to elaborate the index heading. Single passages of text can often encompass a large number of different themes, each of which has to be recorded, usually in the margin of the transcript.
Charting	Rearranging the data according to the appropriate part of the thematic framework to which they relate, and forming charts. For example, there is likely to be a chart for each key subject area or theme with entries for several respondents. Unlike simple cut and paste methods that group verbatim text, the charts contain distilled summaries of views and experiences. Thus the charting process involves a considerable amount of abstraction and synthesis.
Mapping and interpretation	Using the charts to define concepts, map the range and nature of phenomena, create typologies and find associations between themes with a view to providing explanations for the findings. The process of mapping and interpretation is influenced by the original research objectives as well as by the themes that have emerged from the data themselves.

2.2.10.6.1 Familiarisation

This stage of qualitative data analysis involves immersion in the raw data *(or typically a pragmatic selection from the data)* by listening to tapes, reading transcripts, studying notes and so on, in order to list key ideas and recurrent themes. Familiarisation of the data *(see table 2.7)* was the first stage of data analysis conducted by the researcher. Each interview was transcribed by the researcher and it took approximately between 3 to 6 hours to transcribe each interview. Most interviews were transcribed within 24 hours of conducting the cognitive interview. During the transcribing process, the researcher noted any hesitancy or and long pauses by respondents (response latency). Examining response latency can provide the researchers with indications of comprehension problems. Response latency is considered a general measure of the amount of information processing required for response generation.[265] It involves measuring the time from question presentation to response generation.[225] Response generation requires a number of processes *(see section 2.2.10.3.4)*, so therefore response latency can provide an indication of information processing demands. The main assumption of response latency is that difficult or 'bad' questions take longer to answer than easy or 'good' questions. In other words, poorly structured or incomprehensible questions take longer to answer than questions that lack ambiguity. This technique is generally used in conjunction with more in-depth, intensive interview methods.[231] The main limitation associated with this method is that there is no standardised time frame for short and long response times for response generation. There has been no proven association between long response times and inaccurate responses.[266] Short response times may be associated with a lack of question comprehension.[231] Lengthier response times maybe due to a respondent's careful processing as opposed to difficulty in response generation[224] or difficulty with information retrieval.[225] Another limitation of this technique is that response latency is unable to identify the cognitive difficulties being experienced by the respondent.

In order to adhere to the aims of this study, it was more important to focus on *'what'* was said by the respondent than *'how'* it was said. Therefore, denaturalised approach was undertaken during the process of transcribing each interview for analysis.[267] Also, very comprehensive notes were taken during the transcribing process and kept in a notebook. This was done to record any further ideas for the

thematic framework and also for future iterations to the ASAT. It is recommended that this should be done to aid in analysis qualitative data.[268] Each interview transcript was read several times by the researcher. In instances, where there was any difficult terms or phrases, the researcher listened to the recorded interviews to clarify these terms or phrases.

2.2.10.6.2 Identifying a thematic framework

The identification of the thematic framework *(see table 2.7)* was the second stage of data analysis conducted by the researcher. The thematic framework used by the researcher was based on the cognitive models for survey interaction *(see section 2.2.10.4)*. This was an external pre-defined framework applied to data synthesis due to the nature of cognitive processing data. The main overarching themes were comprehension or interpretative problems, information retrieval problems, judgment/decision problems and response formatting/generation problems.

2.2.10.6.3 Indexing

Each question response was analysed and categorised according to the cognitive difficulty *(see section 2.2.10.4.1 to section 2.2.10.4.4)* expressed by respondents. These identified themes were noted in the margins of each transcript *(see table 2.7)*. Each theme was assigned a colour code in the Excel spreadsheet. The corresponding text was colour coded to match identified themes and also sub-themes. During this stage of data synthesis, the researcher was able to identify other emergent themes such as question duplication and ASAT weights and scores. Paper-based mind maps were used to sort identified themes and sub-themes into an index to facilitate the next stage of data analysis.

2.2.10.6.4 Charting

The data was arranged into the appropriate sections of the thematic framework (charting) *(see table 2.7)* and these charts were transposed onto Word documents for ease of data analysis. The index underwent further revisions where necessary, to ensure that all the data were coded. However, it was helpful to have standard themes such as cognitive processes to standardise the data analysis.

2.2.10.6.5 Mapping and interpretation

Mapping and interpretation was the final stage of data synthesis *(see table 2.7)*. This stage of data analysis answered the question *'what were the respondents communicating about the ASAT?'* It was necessary to be very meticulous in the interpretative approach at this stage because these results were going to be used to modify the ASAT. This was important because subsequent versions of the ASAT were going to be used in later validity studies.

2.2.11 Development of ASAT v16 from ASAT v15a

As previously discussed, the results from the cognitive interviews were used to modify and improve the ASAT. The implications of the findings from Study 1 on the development of the ASAT are discussed in *section 3.11.1.* The modifications to ASAT v15a were targeted on the type of cognitive difficulties expressed by respondents. The resolution of comprehension problems *(see section 3.11.1.1)* included the inclusion of a comprehensive glossary in ASAT v16. The resolution of information retrieval problems *(see section 3.11.1.2)* included question rewording. The resolution of judgement/decision problems *(see section 3.11.1.3)* included improving the instructions for completing the ASAT. There were no resolutions of response formatting problems *(see section 3.11.1.4)*. The resolution of other (non-cognitive) reported problems *(see section 3.11.1.5 to section 3.11.1.7)* included merging questions. Also, respondents indicated that there should a domain that specifically measures the roles and responsibilities of clinical microbiologists in ASPs. Therefore, draft questions which were based on current evidence and published guidelines were prepared by the researcher *(see section 3.11.1.8)* for inclusion into ASAT v16. An overview of the modifications conducted on ASAT v15a in order to produce ASAT v16 *(see Appendix X)* are summarised in *Appendix XXIV*.

2.2.12 Ethics and ethical approval

A research passport was applied for and granted prior to the start of this programme of work. Ethical approval for Study 1 was sought on the 4th of November 2010. This involved sending a brief two-page summary of the research study to Elaine Hutchings (Co-ordinator for Northwest 6 REC - GM South and Northwest 8 REC - GM East). The researcher received confirmation of the ethics requirements for Study 1 on the 2nd December 2010. It was decided that Study 1 did not require

ethical approval because the study was classed as service evaluation by the Local Research Ethics Committee *(see Appendix XI)*. Ethical approval from the University of Manchester Research Ethics Committee was deemed unnecessary at the time of the study due to the nature of the data collected.

2.3 STUDY 2: Perspectives of clinical microbiologists on antimicrobial stewardship programmes (ASPs) in NHS Trusts

Study 2 represents the second qualitative phase of the sequential exploratory strategy used in this programme of work. As previously discussed, ASAT v15a was modified as a result of the findings of Study 1. Another key finding of study 1 was that antimicrobial pharmacists indicated that there was little assessment of the role of clinical microbiologists in ASAT v15a. This finding was also confirmed in the results of the literature review conducted prior to the start of this programme of work where clinical microbiologists led approximately 50% of the interventions for implementing ASPs. Therefore, based on these findings, the researcher drafted seven questions which examined the role of clinical microbiologists. These questions were based on the roles and responsibilities of clinical microbiologists summarised below:

- membership on a multidisciplinary antimicrobial stewardship team[5;15;269]
- involvement with the development of antimicrobial policies in collaboration with clinical pharmacists, infectious disease physicians and the Drugs and Therapeutics Committee. The clinical microbiologist should ensure that the AMR trends inform the content of the antimicrobial policies and guidelines[18]
- involvement with the development of antimicrobial formularies in conjunction with the ID physician. The clinical microbiologist should also be involved in the regular review of antimicrobial formularies to ensure that AMR trends inform the content of antimicrobial formularies[4;18]
- involvement with daily ward rounds for critically ill patients in conjunction with ID physicians and antimicrobial pharmacists[18]
- offer advice on antimicrobials specifically restricted antimicrobials prior to prescription to patients with infections[5;13;14;18;269]

The content validity of the draft questions and also the newly revised ASAT (ASAT v16) were tested using cognitive interviews and semi-structured interviews in Study 2.

2.3.1 Aims

- To investigate the content validity of the proposed section for clinical microbiologists
- To determine whether the proposed section for clinical microbiologists should be included in ASAT v17
- To investigate the content validity of the ASAT v16

2.3.2 Objectives

- To determine the content validity of the proposed domain for clinical microbiologists by conducting cognitive interviews with this staff group utilising the draft questions for the proposed domain
- To determine the content validity of ASAT v16 by conducting semi-structured interviews with clinical microbiologists
- To modify and improve ASAT v16 using the findings from the content validity studies in order to produce ASAT v17

2.3.3 Methodological justification

As previously discussed, focus groups were not deemed an appropriate method for testing the validity of the ASAT *(see section 2.2.3)*. Consequently, cognitive interviews were conducted in Study 1 using ASAT v15a. The draft questions on examining the role of clinical microbiologists in implementing ASPs were not previously tested. As a result, it was decided to conduct cognitive interviews on these questions. Semi-structured interviews are used when exploring the perspectives of respondents on a chosen topic area.[270;271] These types of interviews provide the participant with a forum to discuss their perspectives to a series of open-ended questions. In order to achieve the aims of this study, semi-structured interviews were conducted with clinical microbiologists.

2.3.4 Study sites

The study sites for Study 2 were Foundation and Acute NHS trusts as described in *section 2.2.4*.

2.3.5 Sampling

Clinical microbiologists were the target study group for Study 2. Most NHS trusts have at least one 1.0 WTE consultant microbiologist in post.

2.3.6 Inclusion criteria

Clinical microbiologists which also known as medical microbiologists were the target group for Study 2. Participants will be included in this study if they are involved in ASPs within their hospitals.

2.3.7 Exclusion criteria

Clinical microbiologists not involved with ASPs within their hospitals were excluded from this study. Clinical microbiologists were given the opportunity to decline participation in the study. In instances where they indicated that they did not wish to take part in the study, they were also excluded and no further contact was made.

2.3.8 Recruitment of participants

Participant recruitment for Study 2 was recruited in a similar manner to Study 1 *(see figure 2.5)*. However, for this study, clinical microbiologists were the target study group. 10 interviews in total were conducted in Study 2. Nine interviews were conducted in hospitals in the northwest of England. One interview was conducted outside the northwest region.

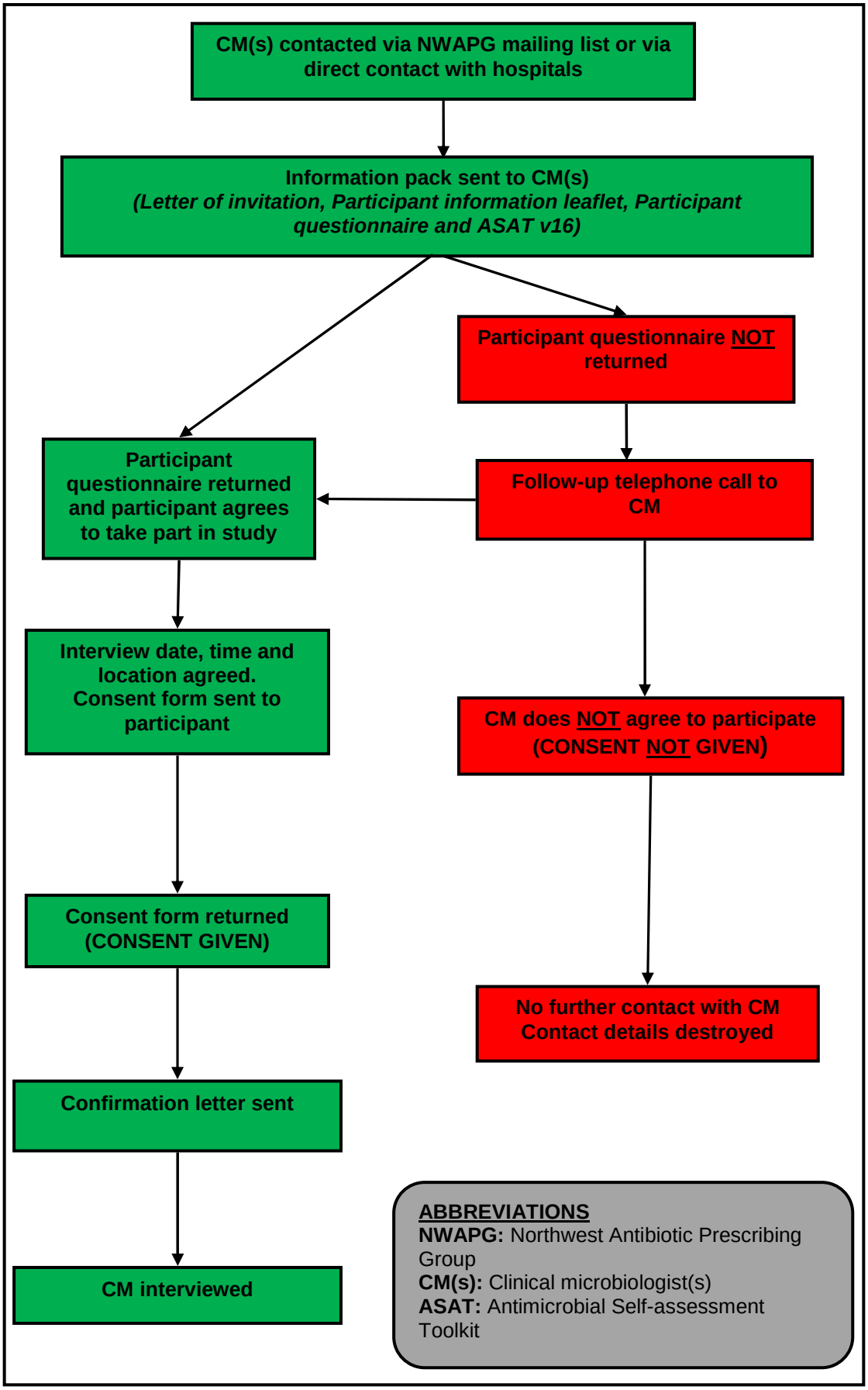

Figure 2.5 - The recruitment strategy used for Study 2 for clinical microbiologists

An information pack which included a copy of the ASAT v16 *(see Appendix X),* a letter of invitation, participant information leaflet, and the participant questionnaire *(see Appendix XII, XIII and XIV)* will be sent to clinical microbiologists who were members of NWAPG. The version of ASAT v16 which was sent as part of the information pack did not contain the proposed section for clinical microbiologists as this section was used to conduct the cognitive interviews.

The researcher was granted access to the NWAPG mailing list by the NWAPG chairperson so therefore clinical microbiologists were recruited via the mailing list. In addition, an information pack was sent to clinical microbiologists who have been identified by direct hospital contact.

Participants who were willing to take part in the research study were asked to contact the researcher by the telephone or email to arrange a convenient time, date and location to conduct the interview. Also, they were asked to return the participant questionnaire at this stage.

In instances, where there was no participant questionnaire returned to the researcher, further contact was made to the clinical microbiologist either by telephone. If the clinical microbiologist indicated that they were unwilling to participate in the study, their contact details were destroyed and no further contact was made to the individual.

In instances where the participant questionnaire was returned, the time, date and location of the interview were arranged. A confirmation letter was sent confirming the details of the interview *(Appendix XV)*. Also, a consent form *(Appendix XVI)* was sent to the participant and was collected before start of the interview. If after reading the consent form the participant was unwilling to take part in the study, their contact details were destroyed and no further contact will be made with the individual. After the interview the participant was sent a thank you letter *(Appendix XVII)* and a summary of the research if requested.

2.3.9 Sample size

As described is *section 2.2.9,* the sample size for cognitive interviews is five to ten participants for each round of testing. A purposive sample of ten clinical microbiologists was interviewed during this round of testing ASAT v16.

2.3.10 Methods

In Study 2, each interview was conducted in two stages in order to collect qualitative data from respondents. Stage 1 consisted of a cognitive interview which was conducted on the draft section on clinical microbiologists. Stage 2 consisted of a semi-structured interview which specifically looked at the perspectives of clinical microbiologists about their hospital's ASPs. The interview protocol *(see Appendix XVIII)* for Study 2 provides an overview of how the interviews were conducted.

2.3.10.1 Cognitive interviews (Stage 1)

On analysis of the current evidence base on the roles and responsibilities of clinical microbiologists in ASPs and also the verbal reports from Study 1, the researcher devised seven potential questions *(see table 2.7)* that could be included in the ASAT. This proposed draft section which examined the role of clinical microbiologists was based on recommendations from guidelines published by the DH and IDSA/SHEA. Cognitive interviews were conducted using these draft questions in order to identify if respondents experienced any cognitive difficulties associated with these questions. The other questions within the ASAT v16 had been previously tested using cognitive interviews in Study 1. Consequently, these questions were not tested in Study 2 using cognitive interviews.

Table 2.7 - The proposed questions examining the roles and responsibilities of clinical microbiologists in ASPs

Proposed questions (Clinical microbiologists)	
1	Is there a clinical microbiologist on your hospital's antimicrobial stewardship committee?
2	Are clinical microbiologists within your hospital involved in the development of antimicrobial policies and guidelines?
3	Are antimicrobial resistance trends used to inform the content of antimicrobial policies and guidelines?
4	Are clinical microbiologists within your hospital in the development of antimicrobial formularies?
5	Are clinical microbiologists involved in ward rounds?
6	Is the reporting of antimicrobial susceptibility testing results in line with formulary choices?
7	Is your hospital actively involved in surveillance or monitoring of antimicrobial resistance trends?

2.3.10.2 Semi-structured interviews (Stage 2)

Semi-structured interviews were conducted with clinical microbiologists to gain insight into their perspectives on ASPs within their NHS Trusts. There were two main reasons for interviewing this staff group. Firstly, one of the key findings from Study 1 was that the AMPs indicated that they felt that the role of the clinical microbiologist was underrepresented in ASAT v15a. Secondly, these interviews were conducted in order to ensure that the ASAT evaluated the pertinent components of hospital ASPs. Semi-structured interviews integrate structured and unstructured exchanges[271] and are typically conducted one to one, that is, one researcher to one participant.[270] Semi-structured interviews are viewed as the most appropriate technique for investigating participants' views and opinions on a particular topic area.[270;271] These types of interviews provide the participant with a forum to discuss their perspectives to a series of open-ended questions.[272] Semi-structured interviews integrate structured and unstructured exchanges.[271] These types of interviews rely on a fixed set or series of questions on the subject area to be explored.[271-273] The respondent was asked to answer each question in his/her own words. Using a fixed set of questions enabled the researcher to use a standardised format when comparing responses.[270;271]

2.3.11 Data collection

Each interview was conducted in two stages. Qualitative data were obtained from respondents using cognitive interviews and semi-structured interviews. In stage 1, cognitive interviews *(see section 2.3.10.3)* were conducted with ten clinical microbiologists in the Northwest SHA using the proposed section for clinical microbiologists (*see table 2.8).* Pre-prepared and spontaneous probes *(see section 2.2.10.2)* were used to guide the interview process; however the interviews remained respondent led (*see Appendix XVIII* - Interview schedule). In stage 2, semi-structured interviews *(see section 2.3.10.2)* were conducted using ASAT v16.

2.3.12 Qualitative data analysis

Cognitive interviews were analysed using thematic or framework charting based on cognitive processing models described in *(section 2.2.10.4)*. Semi-structured interviews were analysed based on the method described in *section 2.2.10.5.2.* This type of interview is not cognitive in nature so therefore a predefined framework was

not used to analyse these data. The analysis of the semi-structured interviews was conducted using a thematic framework *(see section 2.2.10.5.2)*. The thematic framework was derived from the participants' verbal reports and was not based on cognitive processing models. The results from Study 2 are presented in chapter 4 of this thesis.

2.3.13 Development of ASAT v17 from ASAT v16

The results from the cognitive interviews and semi-structured interviews conducted in Study 2 were used to modify and improve ASAT v16. The implications of these findings are discussed in *section 4.6.1*. The most commonly reported cognitive difficulty was the comprehension of terminology used in the draft questions *(see section 4.6.1.1)*. The findings from the semi-structured interviews indicated that respondents agreed that ASAT v16 contained the pertinent aspects for successful ASPs *(see section 4.6.1.2)*. However, most respondents indicated that a section dedicated to measuring their roles in ASPs was essential in future iterations of the ASAT *(see section 4.6.1.3)*. Consequently, a draft section examining the roles of clinical microbiologists was included in ASAT v16. An overview of the modifications conducted on ASAT v16 in order to produce ASAT 17 *(see Appendix XIX)* are summarised in *Appendix XXV*.

2.3.14 Ethics and Ethical approval

Ethical approval for Study 2 was sought on May 11th, 2011. This involved sending a brief two-page summary of the research study to Elaine Hutchings (Co-ordinator for Northwest 6 REC - GM South and Northwest 8 REC - GM East). The researcher received confirmation of the ethics requirements for Study 1 on June 2nd, 2011. It was decided that Study 2 did not require ethical approval because the study was classed as service evaluation *(see Appendix XI)*. Ethical approval from the University of Manchester Research Ethics Committee was deemed unnecessary at that time due the nature of data collected in the study.

2.4 STUDY 3: Investigating the validity of ASAT v17 using Rasch modelling

Study 3 represents the quantitative phase of the sequential exploratory strategy *(see section 2.1.3)* used in validating the ASAT. This research study was a cross-

sectional study which evaluated the antimicrobial stewardship programmes within NHS Trusts. The type of data required for this study was operational hospital data was collected using the ASAT. Patient-specific data was not required or collected for this study.

As previously discussed, a qualitative approach was used to investigate the validity of the ASAT. However, one of the limitations of these methods is that they cannot provide statistical estimates of item responses.[225] Consequently, in order to generate statistical estimates of items responses, Rasch modelling and analysis was conducted on the responses to ASAT v17.

2.4.1 Aims

- To investigate the construct validity of ASAT v17 by using Rasch analysis
- To produce ASAT v18 from the results of the validity testing conducted on ASAT v17
- To investigate the construct validity of ASAT v18 by conducting further Rasch analysis

2.4.2 Objectives

- To collect quantitative data about the participating NHS trusts' ASPs using ASAT v17
- To conduct Rasch modelling on the ASAT domains using the dataset produced by the responses from the participating NHS trusts. These analyses primarily included the examination fit statistics for each domain of ASAT v17
- To examine the overall fit statistics of ASAT v18 in order to assess the construct validity
- To modify ASAT v17 using the results of the fit statistics of each domain in order to improve and produce ASAT v18

2.4.3 Methodological justification

A number of alternative statistical modelling methods such as Factor analysis were considered by the researcher for investigating the construct validity of ASATv17. This section describes the rationale underpinning using an Item Response Theory (IRT) based model such as Rasch Modelling to investigate the construct validity of the ASAT.

Rasch modelling was chosen because it has two main advantages over other methods such as Classical Test Theory (CTT) modelling and Factor analysis. Firstly, Rasch models are based on Item Response Theory (IRT) and the advantages associated with IRT are discussed below *(see section 2.4.9.2)*. Secondly, data analyses using Rasch models can be conducted utilising responses from a small sample size i.e. at least 30 respondents.[274] Rasch modelling requires a sample size of at least 30 respondents in order for the models to be stable. Statistical methods such as exploratory and confirmatory factor analysis, which are special forms of structural equation modelling, would require a sample size of at least 250 hospitals.[275] The sample size required for these methods is greater than 170 acute NHS Trusts in England that met the inclusion criteria.[276] Rasch analysis was therefore chosen because of these reasons.

2.4.4 Study sites

The study sites for this study 3 were Acute Trusts and Foundation Trusts as defined in *section 2.2.4*. In previous studies, participants were recruited from the Northwest Strategic Health Authority. However, participants were recruited from across England for Study 3 in order to achieve the required sample size for testing the construct validity of the ASAT.

2.4.5 Sampling

The ASAT was designed to evaluate ASPs in Acute and Foundation trusts so therefore these types of hospitals were recruited into Study 3.

2.4.6 Inclusion criteria

Foundation NHS trusts and NHS acute trusts in England.

2.4.7 Exclusion criteria

Ambulance trusts, mental health trusts and primary care trusts were not included in the study. Any hospital that indicated that they were not willing to take part in the study was excluded.

2.4.8 Recruitment of participants

NHS trusts were recruited via antimicrobial prescribing groups in England *(see figure 2.12)*. There were a number of active groups at the time of recruitment into Study 3 and there were West Midlands Antimicrobial Pharmacists Group, Northwest Antibiotic Prescribing Group (NWAPG), Hertfordshire and Bedfordshire Antibiotic Network, Yorkshire and Humber Antimicrobial Pharmacists and the Southwest Antibiotic Pharmacy Group. Initially, the researcher made contact to the lead chair of each group in order to request access to their membership lists. The contact details of each chairperson were publicly on the NHS Networks website at the time of study recruitment. The researcher had previously made contact with the chairperson of NWAPG for study recruitment for Study 1 and Study 2 and he granted access for Study 3. The chairpersons from three other groups agreed to allow the researcher to have access to their membership lists. An information pack which included a copy of the ASAT v17, a letter of invitation, participant information leaflet, *(see Appendix XIX, XX, and XXI respectively)* was sent to the members of antimicrobial prescribing groups. Participants who were willing to take part in the research study were asked to contact the researcher by the telephone or email to confirm their participation in the research study. Also, they were asked to return the participant questionnaire at this stage.

In instances, where there was no participant questionnaire returned to the researcher, further contact was made to the antimicrobial pharmacist or clinical microbiologist either by email or telephone. If the AMP or clinical microbiologist indicated that they are unwilling to participate in the study, their contact details will be destroyed and no further contact was made to the individual.

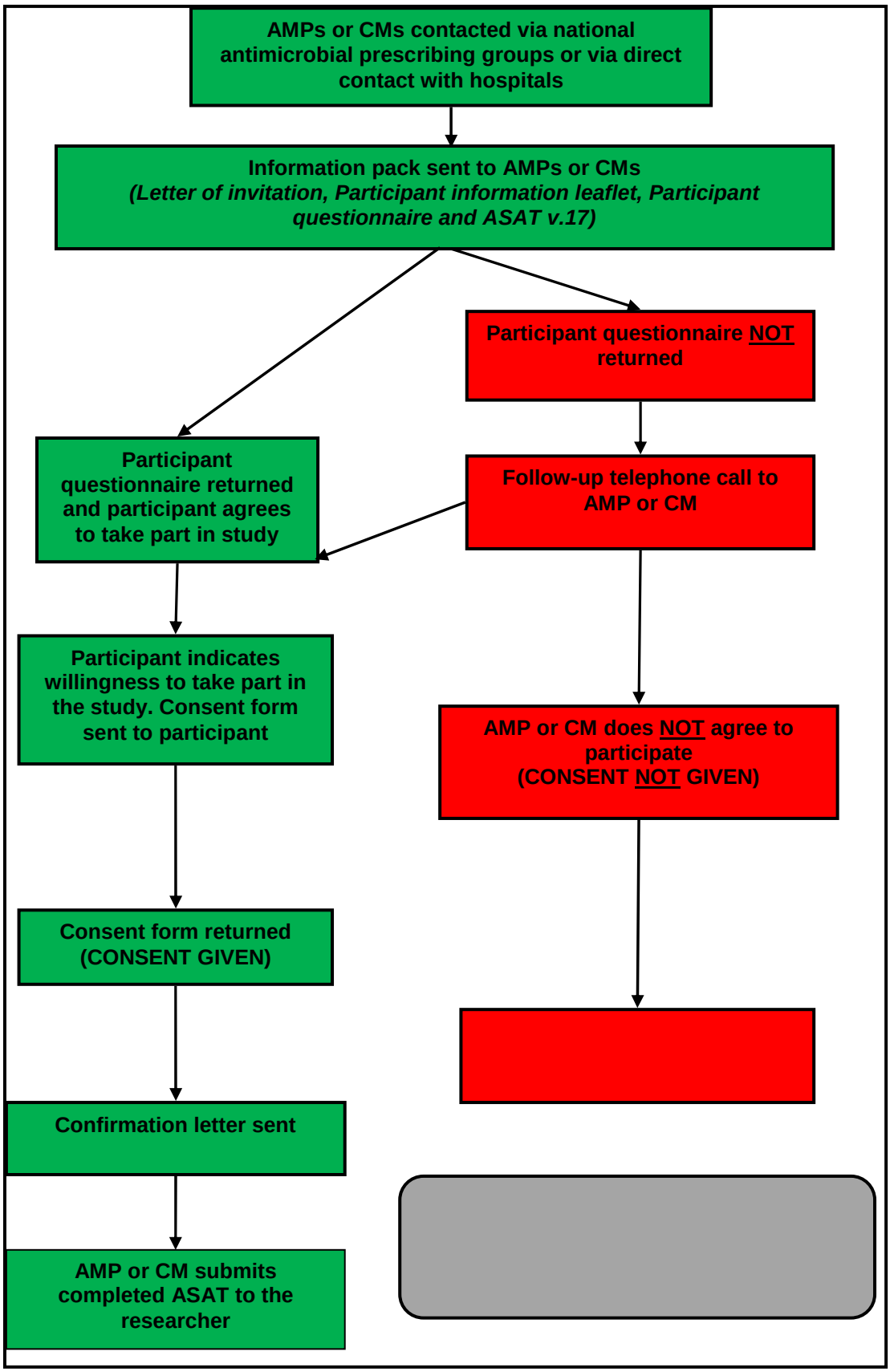

Figure 2.6 - The recruitment strategy used in Study 3 for NHS trusts

In instances where the participant questionnaire was returned and the participant agreed to take part in the study, then a confirmation letter was sent to confirm the requirements for study participation *(Appendix XXII)*. Participation in this study required each participant to complete ASAT v17 and to return the completed ASAT to the researcher by email. After each participant submitted a completed copy of ASAT v17*,* they were sent a thank you letter *(Appendix XXIII)*.

2.4.9 Sample size

As previously discussed *(see section 2.4.3),* the minimum sample size required for Rasch modelling is 30 participants.[230] 33 acute NHS trusts met the inclusion criteria *(see section 2.4.6)* and were recruited for Study 3.

2.4.10 Data collection

NHS trusts were recruited using the recruitment strategy described in *section 2.4.8.* Each AMP or clinical microbiologist was asked to complete ASAT v17 *(see Appendix XIX)* on behalf of their NHS trust. The completed questionnaires were returned to the researcher by email.

2.4.11 Data analysis

The validation process refers to the accumulation of evidence to support validity arguments.[217] In order to achieve the aims of this study, the analysis of the ASAT v17 and ASAT v18 was conducted within the Rasch framework. Also, the analyses were conducted following the guidelines produced by Wolfe and Smith. [274;277] These guidelines are based on the validity definitions proposed by Messick.[217;229] The rationale for choosing an IRT-based model is described in *section 2.4.11.1*. An overview of Rasch model and its applications to testing the construct validity of the ASAT are described in *section 2.4.11.2*.

2.4.11.1 Item Response Theory

The Rasch model *(see section 2.4.11.2)* is considered to be a one parametric Item Response Theory (IRT) model. It was utilised in this programme of work to investigate the construct validity *(see section 2.1.3)* of ASAT v17.

IRT is a model-based measurement in which trait level estimates depend on both persons' (respondent) responses and on the properties of the questions that are

contained with the scale. [278] It has been described by Hambleton and his colleagues as a *'general statistical theory about examinee item and test performance and how performance relates to the abilities that are measured by the items that are measured by the items in the test'*.[279] IRT comprises a set of generalised linear models and associated statistical procedures that connect observed survey responses to a subject's location in an unmeasured underlying latent trait.[280] The benefits of IRT analysis is obtaining empirical support for construct validity, which makes it an essential step in the instrument development process. IRT analysis can result in finer construct interpretations that lead to more thorough descriptions of low-scoring and high-scoring respondents (test subjects).[281]

The basis of IRT is primarily that respondents and items are located along the same continuum. [282;283] Underlying this concept is that IRT-based models assume that the latent variable is represented by a unidimensional continuum.[282] The latent variable, trait or construct can be defined as the construct being measured by a questionnaire. [278;284] In terms of the ASAT, the latent variable being measured is the methods of organisational implementation of AMS.

One of the key fundamental premises of IRT is that an item should be able to differentiate among respondents located along different points along a continuum. Therefore, respondents are characterised in terms of their locations on the latent variable. This ability to differentiate between among respondents and their *'abilities'* is fundamental to IRT and contributes to its advantages over Classical Test Theory (CTT).

More recently, IRT methodology as opposed to CTT has been applied to assess and validate instruments. [285-287] IRT possesses advantages over CTT methodology in terms of assessing the validity of instruments. One limitation of CTT statistics such as item difficulty *(see section 2.4.11.2)*, item discrimination *(see section 2.4.11.2.3)* and reliability *(see section 2.4.11.3.3)* is that there are dependent on the sampled respondents. However, IRT item parameters are independent on the sample used. Also, IRT item parameters are assumed to be invariant across the sample so therefore,

a. the parameters that characterise a subject are independent of the test items from which they are calibrated and,
b. the parameters that characterise an item are independent of the ability distribution of the set of subjects[288]

Another limitation of CTT is that it yields a single estimate of reliability and corresponding standard error of measurement. However, IRT possesses the ability to measure scale precision across the underlying latent variable being measured by the instrument. [284;285] A further disadvantage of CTT is that a participant's score (person trait level) is dependent on the set of questions used for analysis whereas in an IRT-estimated person trait level is independent of the questions included in the analysis. The expected participant's score is calculated from their responses to each item. The IRT estimated score is sensitive to differences among individual response patterns, which makes it a better estimate of an individual's true level along the trait continuum than the summed score in CTT.

IRT-based models facilitates the evaluation of unidimensionality which means that only one construct is being measured by the scale and also local independence where items within a scale should be uncorrelated with each other. From the above discussions, it can be seen that the utilisation of IRT-based models is advantageous to instrument developers. Instrument developers can determine the probability of a test subject giving the correct answer to a test item. This is particularly useful in instances where instrument developers need to know that characteristics of test scores or one or more populations of subjects. Also, they can design tests (questionnaires) with inherent characteristics for a test population. [279;288]

2.4.11.2 The Rasch model

Rasch modelling involves a rigorous testing diagnostic methodology for testing instruments. The Rasch model is based on IRT *(see section 2.4.11.1)* and was developed by the mathematician, George Rasch. It specifies that there should be an expected pattern of responses if measurement is to be achieved. [230] Historically, Rasch models have been used to validate instruments in educational and psychological research. More recently, Rasch models have been used to validate self-report instruments in healthcare for cancer, depression and competency assessments for healthcare professionals. [281;285;286;289] Rasch modelling offers an approach that addresses several methodological characteristics that are associated with scale development and construct validation. [290] Rasch measurement theory (RMT) refers to a family of statistical models and techniques used to assess the quality of tests and questionnaires, and to construct true interval-scale measures

from the raw scores obtained from such instruments.[291] Alternatively, Rasch modelling has also been used to refer to the formal testing of a scale or instrument against a mathematical measurement model.[292] It is a mathematical model of the probability of a favourable response that takes respondent ability (βn) and item difficulty (δi) into account. The Rasch measurement model provides estimates of the *'goodness of fit'* between item difficulty (δi) and respondent ability (βn). Rasch modelling permits *these two terms* to be located on the same scale with parameters within the range of ± infinity. For example, within ASAT v17, which contains items that are dichotomously scored as *'yes'* or *'no'*, it models the probability (P) of responding favourably on item (i) for each participating NHS trust (n). This probability is expressed as follows:

$$P\,(X_{ni}=1) = e^{\beta n - \delta i} / (1+e^{\beta n - \delta i})^{293} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{equation (1)}$$

Therefore, the probability (P) that a NHS trust will endorse, or respond favourably, to an item within ASAT v.17 is modeled as a function of the difference between each NHS trust's ability (βn) and the difficulty of the item (δi). In other words, if a NHS trust is high on the ability or trait being measured (in this case, ASPs) when compared to the difficulty of the item (as determined by item responses), it will have a relatively higher probability of success on that item. From *equation 1*, the probability that a NHS trust will be able to respond favourably to an item equals 50% for a NHS trust with the ability (βn) equal to the item difficulty (δi). In other words, the item difficulty (δi) is equal to the ability (βn) for hospitals that have a 50% probability of endorsing the item. Rasch modelling is unable to provide estimates for perfectly scored items because the estimates are based on probability of success to probability of failures ratios.[230]

One of the main advantages of Rasch modelling is that it locates both respondent (in this case, NHS trust) and item parameters along the same scale. The application of Rasch models that are IRT- based models also has a number of advantages over CTT. Firstly, the Rasch model transforms data or 'raw scores' into a linear scale. The model constructs interval measures from raw data such as ASAT raw scores. This is beneficial to the data analysis, because the organisation of the data by the Rasch model facilitates a perfect Guttmann order of response probabilities. Consequently, the item and respondent parameters are produced so that item and respondent

calibration are on a common interval scale. Additionally, Rasch models require that items are invariant across the population under investigation and it is independent on the characteristics of population under investigation. Secondly, the ASAT item properties such as item fit *(see section 2.4.11.3.1)* can be tested against a mathematical measurement model that proposes a relationship between the respondent ability, the item difficulty and the probability of endorsing an item.[294-296] Thirdly, the respondent scores can be calculated without replacing missing responses. Finally, the assumption of unidimensionality (a measure should only capture a single dimension) can be investigated or tested explicitly [292] It has been hypothesised that Rasch models are the only models that deal with problems related to measurement. This is primarily due to the ability of these measurement models to produce linear measures, adjust for missing responses, and to detect both item and respondent misfit.[296] In summary, Bond and Fox (2007) states that '*the Rasch model incorporates a theoretical idealisation (or construct) of the data's interrelations, which is represented mathematically as an ideal straight line.*'[230] The Rasch model incorporates an algorithm that expresses the probabilistic expectations of items and respondents.[297] The perfect state of measurement is unachievable; however, the interrelations between the items and respondents can be investigated utilising mathematical measurement models such as Rasch models.

As previously discussed, the Rasch model produces an interval scale that determines '*item difficulty'* and '*respondent ability'* measures. The items are arranged on the scale according to the likelihood of being endorsed by respondents, that is, easier items are located at the bottom of the scale and harder items are located at the top of the scale. Additionally, the (same) scale is used to the respondent ability in relation to the items on a unidimensional scale. The scale is measure in logits (log odds units) which are linear. Log odds units or a logarithmic transformation of the odds of success has a range of ± ∞ and is calculated by the conversion of raw score into success: failure ratio or odds and is usually expressed to two decimal places as follows *(equation 2)*:

$$\log\left(\frac{\Pr obability \cdot of \cdot success}{\Pr obability \cdot of \cdot failure}\right) \equiv Ability - Difficulty$$

This log odds or logit equation underpins the principle formula for Rasch family of models including the Partial Credit Model (PCM).[230] Each respondent and item is assigned a score which is dependent on where they fall on the scale. The logit (log-odds) scale can be defined as an interval scale in which the unit intervals between the locations on the Respondent-Item map *(see figure 2.7)* have a consistent value.[230] The use of a calibrated logit scale instead of unstandardised raw scores facilitates a standardised comparison between respondents and items. Rasch modelling software programs such as WINSTEPS perform a logarithmic transformation of item and respondent data in order to yield an interval scale.[298] Item and respondent misfit is observed when the data does not match the ability or difficulty estimates, which results in item measurement imprecision. In other words, $0/x$, where x is the number of respondents yields infinitely small or negligible estimates. [230]

The Rasch assumptions of unidimensionality *(see section 2.4.11.2.1)* and also local dependence *(see section 2.4.11.2.2)* and item discrimination *(see section 2.4.11.2.3)* are discussed below.

2.4.11.2.1 Unidimensionality

Unidimensionality refers to an instrument's ability to measure one trait or attribute at a time hence construct validity.[230] Instrument developers need to ensure that the instrument possesses this characteristic because the generalisability of the results from an instrument's will be negatively affected when it measures a number of traits or attributes concurrently. If this occurs, the final score becomes less useful in estimating the trait under investigation, in other words the estimates could be potentially be confounded with other attributes not intentionally targeted by an assessment. The meaning of any estimates is only useful if each question contributes to the measure of a single attribute.

As previously mentioned, items should contribute meaningfully to the construct or attribute being measured. The Rasch model focuses on the concept of construct validity by assuming that recorded scores are a reflection of the underlying construct.[230] Also, Rasch modelling provides fit statistics that provide indicators of how well each item fits within the underlying construct. The concept of *'fit'* can be

viewed as a quality control mechanism that allows the investigator to assess whether the assumption of unidimensionality holds.

Unidimensionality was assessed using fit statistics, where fit statistics have an expected value of 1.0 and can have a range for 0 to infinity; where any value > 1 indicates the presence of noise or lack of fit between items and the model and any value < 1 indicates that there is item redundancy or overlap.

Fit statistics *(see section 2.4.11.3.1)* were used to assess and to observe how well the data fit the expectations of the model. Misfitting items required further investigation in order to understand the reasons why the misfit has taken place. Misfitting items introduce noise into the instrument and will diminish its ability to measure the underlying latent trait.[230] Any deviations from the Rasch model expectations will be assessed. Also, data from qualitative studies (Study 1 and Study 2) was triangulated with the quantitative data from Rasch modelling to investigate item misfit. It is hypothesised that the removal of misfitting items or item reduction would result in improved measurement properties and potentially reduce respondent burden. [289]

2.4.11.2.2 Local independence

The assumption of local independence states that once all the latent traits that contribute to performance measurement on a set of items are determined, the responses to the items are statistically independent.[299] This assumption assumes that the response of a person to a question does not affect the responses to other questions.[300] In other words, each item within a questionnaire should operate independently of each other and contribute to the questionnaire discretely.

2.4.11.2.3 Item discrimination

Item discrimination is based in the ability of items within an instrument to discriminate between respondents with greater or lesser ability to respond favourably to or endorse items. In other words, item discrimination indicates the extent to which success on an item corresponds to success on the whole instrument. Each item within an instrument should collaborate, in order to generate meaning overall scores. Therefore, any item with negative or zero item discrimination undermines the instrument and any item with positive item discrimination is generally productive for measurement.[301]

The Rasch assumptions as previously described in *section 2.1.11.2.1 to section 2.4.11.2.3* underpin the validity testing conducted by Rasch measurement models.

2.4.11.3 Data analysis using the Rasch modelling (Partial Credit Model)

The PCM belongs to a family of Rasch models and therefore holds some of the Rasch assumptions which are based in IRT. The PCM was developed by Geoff Masters.[230;302] It incorporates the possibility of having more than one option within each response category for example Q2.2 where the response options are 3=both prescription and notes, 2=prescription only or 1= notes only. These types of response categories are also known as polytomous alternatives within an instrument. The PCM was used to analyse responses that have more than two ordered responses categories. It rewards *'partial credit'* for responses which are intermediately, that is, responses that lie between two extremes such as *'yes'* or *'no'* [302;303] The PCM is expressed in the *equation 3* below:

$$P\{X_{ni} = x\} = \frac{e^{x(\beta_n - \delta_i) - \sum_{k=1}^{x} \tau_{ki}}}{\sum_{x=0}^{mi} e^{x(\beta_n - \delta_i) - \sum_{k=1}^{x-1} \tau_{ki}}}$$

where $P\{X_{ni} = x\}$ is the probability for person or respondent (NHS trust) (n) with ability β_n receiving x points on item (i) with difficulty parameter (δ_i), where $x \in \{0, 1, 2, \ldots, m\}$. An item with $m + 1$ ordered response categories has m thresholds τ_k where $k \in \{1, 2, \ldots, m\}$. The threshold parameter τ_k takes on values along the same continuum like β_n and δ_i. Equation 3 specifies a model that is unidimensional (measuring a single dimension), where the '*item difficulty'* parameter and the *'respondent ability'* parameter are located on the same scale or continuum (see *section 2.4.11.2*).[303-305]

Respondent (NHS trust) ability and item difficulty were estimated, in order to produce logits or log-odds. Logits are independent of both the items and samples used.[230] All analyses were conducted using WINSTEPS software which has been specifically designed for Rasch modelling.[306] The outputs produced by WINSTEPS which were analysed by the researcher were item statistics, NHS trust statistics and the item/respondent (NHS trust) maps.

As previously discussed, the main Rasch assumptions are unidimensionality (*see section 2.4.11.2.1)*, local independence *(see section 2.4.11.2.2)* and item discrimination *(see section 2.4.11.2.3)*. The investigation of construct validity can be strengthened if the degree of fit responses (scores) with the theoretical rationale underlying score interpretation is explicitly evaluated.[216] This definition proposed by Messick was used to investigate the construct validity of the ASAT. The concept of *'fit'* was examined by the investigation of the fit statistics *(see section 2.4.11.3.1)* produced by Rasch modelling. Fit statistics provides indicators of how well each item fits an underlying construct. Hence these statistics provide useful information regarding whether the assumption of unidimensionality holds up empirically.[230]

2.4.11.3.1 Fit statistics (Analysis of fit)

Prior to the analysis of fit or, in other words, prior to estimates being used as calibrations, it is necessary to verify that the derived data are suitable for measuring.[230] The validity of the item responses patterns should be examined during item calibration, in order to investigate model fit.[307] The test for unidimensionality can be conducted utilising the fit statistics (statistical coherence to the measure) produced by the PCM.[230] Fit statistics are the degree of fit of the items and the respondents to the theoretical model *i.e*. PCM. They assume that the observed probabilities of response are normally distributed and deviate from the expected or theoretical model by amounts that can be summed or tested.[308] They are calculated by the mean squared deviations of the difference between expected values and the observed values. Bond and Fox (2007) states that *'fit statistics can help to determine whether the item estimations may be held as meaningful quantitative summaries of the observations i.e. whether each item contributes to the measurement of only one construct'*. [230]

As previously discussed, each item should contribute meaningfully to the construct or concept being investigated. This premise underlies the Rasch assumption of local independence *(see section 2.4.11.2.2)*. Fit statistics are one of the outputs from Rasch modelling and they provide an indication of how well the data fit within the underlying construct.[230] Within the Rasch measurement framework, the concept of *'fit'* is viewed as a quality control mechanism and aids in the empirical determination of whether there has been assumption of unidimensionality within the model.

Item fit statistics

Item fit statistics are indicative of how accurately the data fit the model or in other words, there are indicative of the degree to which the data is fulfilling or compliant to the assumptions of Rasch models (unidimensionality). Additionally, they are viewed as indicators of construct validity hence unidimensionality *(see section 2.4.11.2.1).* Fit statistics such as INFIT MNSQ, which are one of the outputs of WINSTEPS, indicate whether items/respondents 'fit' the PCM. Items which do not fit the unidimensional construct, that is, underfitting or overfitting items, have diverged from the expected ability or difficulty pattern.[230] These items may warrant further investigation in order to improve the instrument. Therefore, misfitting items (underfitting items that may be due to erratic responses or too much variation) indicate that the Rasch assumption of unidimensionality is not being satisfied by the data. Hence, misfitting items/respondents threaten construct validity and may require further enquiry such as the interrogation of qualitative evidence. These items degrade the quality of the measure. Misfitting items may be examining other dimensions external to the instrument under investigation (ASAT v17). Overfitting (determinacy or Guttmann style responses - little variation) items or overly predictable items may be indicative of linkage to other items within the item pool; hence they do not satisfy the Rasch assumption of local independence *(see section 2.4.11.2.2)*. These items may lead to the conclusion that the instrument is better than it actually is, because they yield Guttmann-like responses. These items are detected when the INFIT MNSQ statistics are too low. Overfitting items indicate that there is a lack of local independence in other words; the items are not working independently of each other within the instrument. The Rasch model is probabilistic or stochastic and regards Guttmann type responses as too rigid.
Also, the latter may indicate that the items lack the ability to discriminate between respondents, hence not satisfying the Rasch assumption of item discrimination.[309;310]

In chapter 5, item statistics or NHS trust statistics were presented by entry order *(see table 2.8)* and provided data on the following parameters:

Table 2.8 - Item statistics: Entry order (Output example - Domain 1)

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
1.1	x	x	x	x	x	x	x	x
1.2	x	x	x	x	x	x	x	x
1.3	x	x	x	x	x	x	x	x
1.4	x	x	x	x	x	x	x	x
1.5	x	x	x	x	x	x	x	x
1.6	x	x	x	x	x	x	x	x
1.7	x	x	x	x	x	x	x	x
1.8	x	x	x	x	x	x	x	x
Mean	x	x	x	x	x	x	x	x
S.D	x	x	x	x	x	x	x	x

Nb. 'x' denotes estimation statistics produced by WINSTEPS

ITEM or ITEM NUMBER was the sequence number of items in the dataset and this reference number was used for item deletion where indicated.

TOTAL SCORE or RAW SCORE was the raw score corresponding to the items within each domain or the sum of the scored responses to an item by the NHS trusts.

COUNT was the number of data points used to construct measures.

MEASURE was the estimate (or calibration) for each domain, that is, respondent or 'NHS trust' ability or the item difficulty .Values were reported in logits with two decimal places. If the score is extreme, a value was estimated, but as MAXIMUM (perfect score) or MINIMUM (zero score). In instances where no measure was reported, the item was DROPPED from the analysis.

MODEL Standard Error (MODEL S.E) was the standard error of the estimate. These values were reported in logits with two decimal places.

INFIT MNSQ (INFIT MEAN SQUARE): This is an in-lier pattern sensitive statistic. It is based on the conventional chi-square statistic (χ^2) and each observation is weighted by its model variance. It is a *t*-standardised information-weighted mean square statistic, which was more sensitive to unexpected patterns of responses by respondents on items which are near the respondent's measure level. Items with an INFIT MNSQ value between 0.7 and 1.3 were considered productive for measurement *(see table 2.9).*

Table 2.9 - The parameters of the INFIT MNSQ values for item statistics which were productive and unproductive for measurement[230;306]

Value	Definition
>2.0	Off-variable noise is greater than useful information. Degrades or distorts measurement. Always remedy the large misfits first. (misfitting items)
>1.3	Noticeable off-variable noise. Neither constructs nor degrades measurement. Unproductive for construction of measurement, but not degrading (misfitting items)
0.7 to 1.3	Productive of measurement
<0.7	Overly predictable and are less productive for measurement. Misleads us into thinking we are measuring better than we really are. (Attenuation paradox). May produce misleading reliabilities or separations. Misfits <1.0 are only of concern when shortening a test. (Overfitting items)

OUTFIT MNSQ (OUTFIT MEAN SQUARE): This is an outlier-sensitive fit statistic and is based on the conventional chi-square statistic (χ^2). It is a *t*-standardised outlier-sensitive mean square fit statistic, which more sensitive to unexpected behaviour by respondents on items far from the respondent's measure level. In other words, it is more sensitive to unexpected observations by respondents to items which are either relatively very hard or very easy for them to respond favourably and *vice versa*.

The mean square (MNSQ) is the chi-square statistic (χ^2) divided by its degree of freedom and the expected value tends towards zero. Mean squares are corrected for sample size. The values greater than 1 are indicative of unmodelled noise or other sources of variance within the data and hence indicate model underfit. Values less than 1 indicate that the model predicts the data too well and hence indicate model overfit.

Items were retained or removed from the analysis based on the INFIT MNSQ values produced by WINSTEPS. The primary focus was placed on investigating the removal of items which were observed to be underfitting the model, that is, INFIT MNSQ values greater than 1.3. For example, if an item has an INFIT MNSQ of 1.6, this suggests a deviation from unidimensionality in the data, and is considered as potentially degrading measurement.

ZSTD (z-standardised): This is the INFIT or OUTFIT mean-square fit statistic *t*-standardised to approximate a theoretical "unit normal" distribution. For example, a significance of p=0.05 corresponds to 1.96 *(see table 2.10)*. In other words, it reports

the statistical significance or probability of the chi-square (χ^2) statistics or mean square occurring by chance when the data fit the Rasch model.

Table 2.10: The ZSTD statistics and the corresponding *p*-values

Z -standardised statistic (ZSTD)	*p*-values
1.00	0.317
1.96	0.050
2.00	0.045
2.58	0.01
3.00	0.0027
4.00	0.00006
5.00	0.0000006

The relationship between mean square and the z-standardised statistic is shown in *figure 2.7*. The standardised statistic is insensitive to misfit with samples of less than 30 observations and overly sensitive to misfit when there are more than 300 observations.

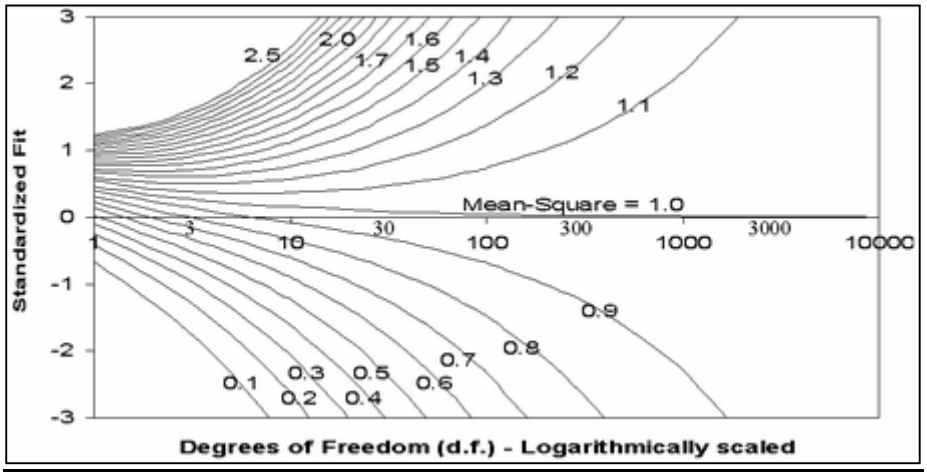

Figure 2.7: The relationship between standardised fit and degrees of freedom

MEAN: This is the average value of the statistic

STANDARD DEVIATION (S.D): This is the standard deviation of the sample

2.4.11.3.2 Item/Respondent (NHS trust) distribution map

In the item/respondent distribution map, the respondents were distributed by the ASAT items. This output was also examined to identify hierarchy of items within the ASAT. Also, this map provided a distribution from the highest scoring NHS trust(s) at

the top of the map (highest positive logit position) to the lowest scoring NHS trust(s) at the bottom of the map (lowest negative logit position) *(see figure 2.8)*.

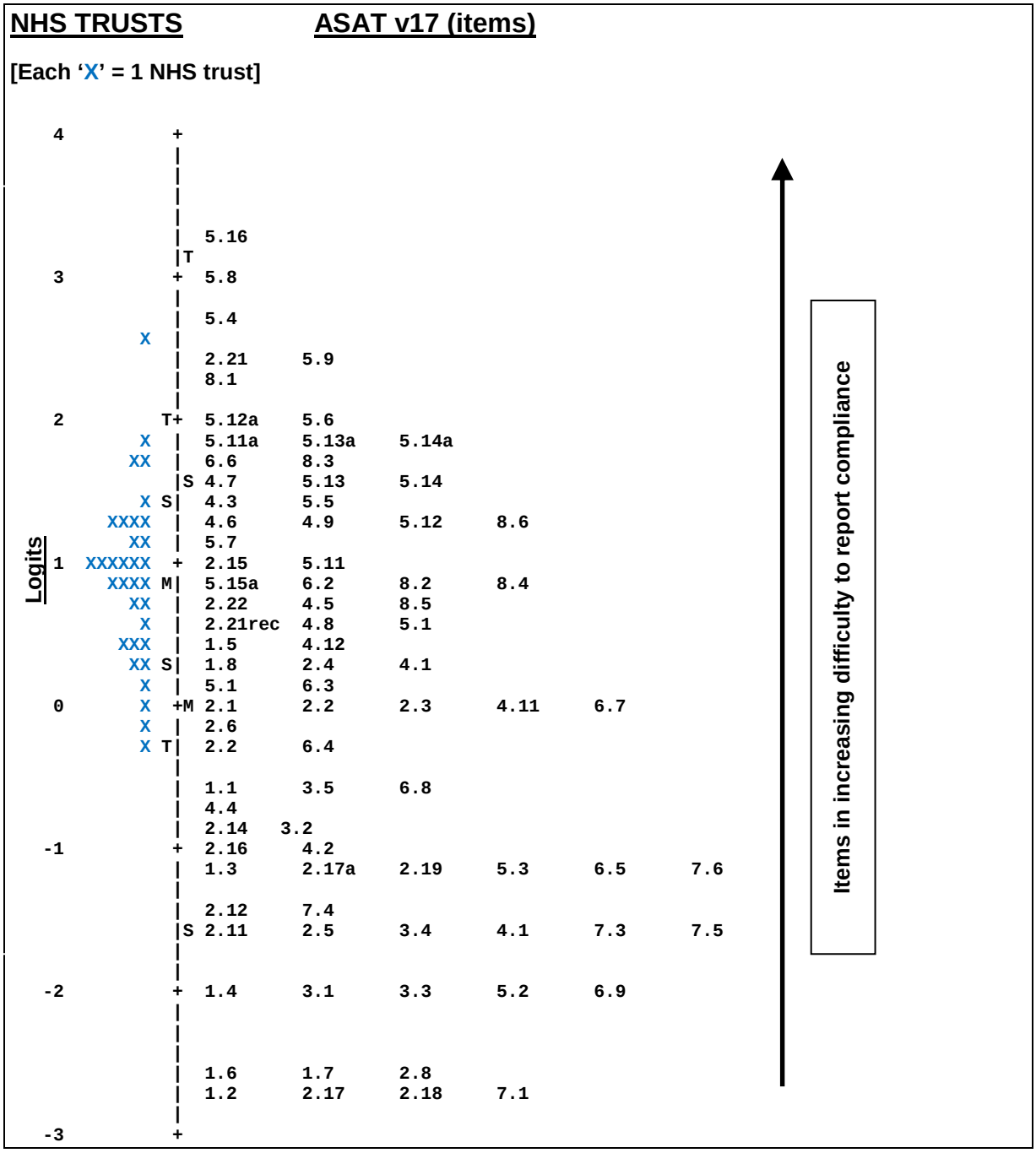

Figure 2.8 - Item/Respondent (NHS trust) distribution map (Example output)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust

The right hand column of distribution map places items in a logit position that is equal to the estimated item difficulty. An indication of a well constructed measure is that the items are line up with the respondents (item targeting). The left hand column

of the distribution map places respondents (NHS trusts) in a logit position which equates to their *'ability'* to endorse or report compliance to items within the construct. Respondents (NHS trusts) with a greater ability to endorse items were located at the highest (positive) logit position. NHS trusts with the least *'ability'* to endorse or report compliance to items were located at the lowest (negative) logit position along the unidimensional latent variable. An indication of a well-constructed measure was that the NHS trusts were normally distributed around the item distribution.

2.4.11.3.3 Reliability Index - Partial Credit Model

Rasch modelling also produces reliability indices for respondents and items. The reliability indices do not necessarily provide evidence to support validity arguments but they are indicative of the reliability of the scores using the ASAT. The respondent reliability index indicates the replicability of a respondent ordering that could be expected if this sample population were given another parallel set of items measuring the same construct.[303] Also, it provides the analyst with confidence in the ability estimates.[230] The respondent reliability requires ability estimates that are well targeted by an item pool and also a large enough spread of ability across the sample, so that the measures adequately demonstrate ability hierarchy (person separation) on the underlying construct. [311] A high respondent reliability is indicative of a well-constructed instrument, where some respondents are high scoring and some are low scoring. Consequently, the inferences regarding the respondent reliability are consistent. [230]

The item reliability index indicates that the replicability of the item positions along the logit (log-odds) scale would be analogous if the items were given to another sample with the same number of respondents.[303] A high item reliability indicates that the instrument is well constructed and that there is good item targeting within the instrument. In other words, some items are difficult and some are easy, and if the items were administered to another sample with the same sample size, then the inferences regarding the item reliability would be consistent. Low item reliability indicates that there may be imprecision or errors of the estimates and that further data collection maybe required in order to reduce the imprecision of estimates. [230]

2.4.12 Creation of ASAT v18 from ASAT v17

An iterative process was used to identify which items were productive for measurement and not productive for measurement, and subsequently identifying which items should be included in ASAT v18 *(see section 5.5.11)*. The fit statistics of each domain and the overall ASAT v17 were examined. For domains 1 to 8, items which were identified as misfitting were removed from the analysis by the researcher and the fit statistics were re-examined. Items which received perfect scores were dropped from the analyses by WINSTEPS. The modifications made to ASAT v17 in order to produce ASAT v18 *(see Appendix XXVII)* have been detailed in a modification table *(see Appendix XXVI)*.

2.4.13 Ethics and ethical approval

Ethical approval for Study 3 was sought on September 1st, 2011. This involved sending a brief three-page summary of the research study to Ethics Committee at Salford Royal NHS Foundation Trust. The researcher received confirmation of the ethics requirements for Study 3 on September 22nd, 2011. It was decided that Study 3 did not require ethical approval because the study was classed as service evaluation *(see Appendix XI)*. Ethical approval from the University of Manchester Research Ethics Committee was deemed unnecessary as the study had been classed as a service evaluation.

2.5 Study 4: OLS regression modelling and analysis (ASAT v18)

Study 4 represented the second quantitative phase of the sequential exploratory strategy *(see figure 2.1.3)* used in this programme of work. The results of the Rasch modelling and analyses conducted in Study 3 were used to generate ASAT v18. Also, NHS trust *'ability'* estimates were generated from these analyses and were used in the regression modelling conducted in Study 4.

2.5.1 Aims

- To investigate the ability of the validated measure (ASAT v18) to predict or model the *Clostridium difficile* rates of participating NHS trusts

2.5.2 Objectives

- To investigate the magnitude and direction of the correlation between the predictor and outcome variables by calculating the correlation coefficient
- To determine the linear relationship (or approximately linear relationship) between the predictor (NHS trust *'ability'* estimates or calibrations) and outcome (CDI rates) variables by conducting simple OLS linear regression analyses on each domain and the overall measure (ASAT v18)
- To examine the analysis of variance (ANOVA) of the regression model i.e. residual sum of squares (RSS)

2.5.3 Methodological justification

Different types of regression analyses were considered by the researcher in order to examine the association, if any, between the predictor (NHS trust *'ability'* estimates) and outcome variables (NHS trust CDI rates). These two variables under investigation in Study 4 were both continuous variables. Logistic regression analyses are used in instances where the independent variables are categorical or a dichotomous outcome.[312;313] Consequently, it was decided that logistic regression was unsuitable for the investigation of the associations, if any, between these two variables. Multiple regression analyses are conducted where there is more than one predictor variable[313] so therefore this method was not suitable for this study. OLS regression modelling is a statistical technique that enables the investigation of the strength and direction of associations between two continuous variables. [314-316] Also, this method is used to evaluate the impact of a predictor variable on an outcome variable.[317] In this study, only two variables were under investigation, that is, NHS trust *'ability'* estimates and CDI rates so therefore OLS regression was used to predict the association between these two variables. The underlying hypothesis for the OLS regression analyses was that the predictor variable (CDI rates) was related to the ability of NHS trusts to respond favourably to the items within the ASAT.

2.5.4 Study sites

The study sites for study 4 were the same as study 3 *(see section 2.4.4)*.

2.5.5 Sampling

The sampling conducted in study 4 has been previously described *(see section 2.4.5).*

2.5.6 Inclusion criteria

The inclusion criterion for study 4 has been previously described *(see section 2.4.6).*

2.5.7 Exclusion criteria

The exclusion criteria for study 4 have been previously described *(see section 2.4.7)*.

2.5.8 Recruitment of participants

The participant recruitment strategy has been previously described *(see section 2.4.8)* and this strategy was used to recruit NHS trusts for study 3. The NHS trust estimates generated by Rasch modelling and analysis were sources from the participating NHS trusts.

2.5.9 Sample size

The sample size for this study was 33 NHS trusts *(see section 2.4.9)*.

2.5.10 Data collection

OLS linear regression modelling was conducted to investigate the predictive and discriminative validity of the ASAT v18. The dependent variable was CDI rates for NHS Trusts. These rates were obtained from the Health Protection Agency (HPA) which produces annual counts and rates of *C.difficile* for NHS Trusts in England.[318] These data were publically available on the HPA website. The *C.difficile* rates used were from April 2011 to March 2012. There were two reasons for utilising this time period. Firstly, these data were the most current data available on *C.difficile* rates available from the HPA. Secondly, this time period corresponds with the period of used for the ASAT evaluation by NHS Trusts for Study 3. The statistical analyses were conducted using IBM SPSS v.20.

2.5.11 Data analysis

Linear regression is a mathematical technique that attempts to describe the relationship between two or more variables with a linear or straight-line function.[312] There are four fundamental assumptions of linear regressions and there are as follows:

- linear regression analysis or modelling assumes that there is linear relationship between the variables under investigation. In other words, as the points increase along the *x*-axis then there is an increase in the values along the *y*-axis
- the variation around the regression line is constant, this is also known as homoscedasticity.
- the variation of the data around the regression line is normally distributed at all values of the predictor variable
- the deviation of each data point from the regression line is independent of the deviation of the other data points[314;316]

Ordinary Least Squares (OLS) regression is a generalised linear model technique that may be used to model a single response variable.[316] It is commonly used where there is a single outcome or dependent variable and a single predictor or independent variable.[312;319] These variables are known as the dependent variable and the independent variable. The dependent variable is also known as the outcome or response variable and can be defined as the variable which researchers are trying to predict.[319] The independent variable is the variable that researchers try to evaluate. For Study 4, the NHS trust *'ability'* estimates are the predictor variable and the CDI rates are the outcome variable.

A number of approaches are used to estimate the linear regression model such as maximum likelihood and ordinary least squares (OLS) or method of least squares. In instances where there is only one independent variable, a scatter plot is commonly used to observe the relationship between the variables under investigation.[314] The regression line also known as the least squares line is the line that most closely fit the data points. This regression line attempts to describe the relationship between two or more variables with a linear or straight-line function.[312]

The equation for a line to model the relationship between two variables and the equation is as follows:

$z = kx + c$ ……*equation 4*

where, if z is the outcome variable and x is the predictor variable then k is the regression coefficient that represents the slope of the linear relationship between the variable x and z, and c is a constant. The regression coefficient k describes the change in x that is associated with a unit change in z. This coefficient provides an average of the expected change of the observed data scattered around the regression line.[314;316] The constant c is called the *'c intercept'* because this is the value of z where x=0 and the regression line crosses the z axis.[312;319]

OLS regression analyses provide data on the model parameters and the confidence intervals for the regression coefficient. Additionally, model fit can be determined by examining the 'goodness *of fit'* of the model, in other words how well the model fits the data. These analyses were conducted by comparing the observed scores with the scores predicted by the model. The difference between the observed scores and the estimated scores are known as the residuals.

The analysis of the residuals provided an indication of how well the model predicted each data point. The residuals were calculated using *equation 5 (calculation of deviance)*. Subsequently, the deviances were summed for all data points after they were squared to remove any negative values. The sum of all the squared residuals is known as the residual sum of squares (RSS). This stage of analyses provided a measure or an indication of how much the data deviates from the overall model (provides a measure of model fit).

The distance of each data point from the regression line is called the error or residual. The sum of the squared errors (SSE) could be calculated by summing the squared values of the residuals *(see equation 5 below)*.

$$\mathrm{SSE} = \sum_{i=1}^{n} (X_i - \widehat{X}_i)^2.$$

where X_i *i*s the observed value, X_i is the predicted value. The regression coefficient and the intercept along the regression line can be calculated if there is only one independent variable.[312;314]

The SPSS outputs for OLS regressions are as follows:

- **correlation coefficient** or the Spearman rank correlation coefficient (ρ) ranges from -1 to +1 and describes the magnitude and the direction of the association between the variables under investigation where, a positive correlation indicated by a (+) sign indicates that as one variable increases so does the other. A negative correlation is indicated by a (-) sign and indicates that as one variable decreases so does the other variable. The absolute value indicates the strength of the correlation for example a perfect correlation of +1 or -1 indicates that the value can be determined exactly by knowing the value of the other variable.[320;321] A correlation value of zero indicates that there is no correlation between the variables under investigation.
- **coefficient of determination (R^2)** which measures the proportion of variation in the outcome variable which is explained by the regression model and ranges from 0% to 100%.
- **analysis of variance (ANOVA)** which is a test of significance of linear association where $p<0.05$ implies a linear association between outcome and predictor variables.[319]

Prior to conducting simple linear regressions, correlation analyses are conducted to investigate the relationship between independent and dependent variables. The analyses would provide an indication of the relationship between two variables (bivariate correlation) therefore the variables could be positively related, negatively related or not related. In other words, correlation analyses are used to describe the strength and direction of the linear relationship between two variables.[321] These analyses were conducted using SPSS v20. The Spearman rank correlation coefficient (*ρ*) was used to interpret the correlations because it can be applied to continuous variables such as CDI rates and *'ability estimates'* obtained in Study 3. A scatter plot was used in order to view the relationship between the variables for each domain. The estimates obtained from Rasch modelling were plotted against the CDI rates using scatter plots in SPSS.

2.5.12 Ethics and ethical approval

The NHS trust estimated generated in Study 3 were used for the OLS regression modelling conducted in Study 3. The CDI rates for the participating NHS trusts were

freely available of the HPA website. Ethical approval for this study was granted on September 22nd, 2011 *(see section 2.4.13)*.

2.6 Chapter summary

This chapter has described the programme of work conducted to validate and improve the ASAT. It discussed at the aims, objectives and also presents a rationale for the chosen methodologies. This programme of work was undertaken in four sequential studies and the results for each study are discussed in the following chapters.

CHAPTER 3:

The investigation of the content validity of ASAT v15a

3. INTRODUCTION

As previously discussed in Chapter 2, questionnaires or survey instruments such as the ASAT should be tested in order to investigate their validity. The process of testing the validity (such as content validity) of questionnaires or survey instruments is an essential phase of questionnaire development. Validating a questionnaire or an instrument is a process where the degree or level of confidence that can be placed on the inferences that are made about the target population based on the scores from the measure.[214] It is a process of accumulating of evidence to support validity arguments.[217] This process is necessary to ensure that the inferences based on the questionnaire are credible and reliable.[322]

Chapter 3 presents the findings from the first qualitative study which investigated the content validity of ASAT 15a. This study represents the first stage of the sequential exploratory strategy *(see figure 2.1)* used in this programme of work. This chapter presents of overview of the main findings from the cognitive interviews conducted with antimicrobial pharmacists. The findings have been categorised according to the cognitive difficulty expressed by the respondents. Other emergent themes are presented in this chapter such as question duplications, double-barrelled questions and irrelevant key concepts or questions. These themes were not necessarily cognitive in nature however they represent problems identified by respondents when completing ASAT v15a. Respondents commented on the relevance of some questions to their current hospital practice therefore these are discussed as well. The findings from this study were used to modify ASAT v15a and subsequently produce ASAT v16. This chapter also provides a rationale for the modifications made to ASAT 15a. These modifications were used to improve the content validity *(see section 3.1)* ASAT by addressing the identified problems with item or question design and also the overall instrument. These problems could have potentially led to response error and measurement error if unaddressed.

3.1. Content validity

Content validity can be defined as *'the determination of the content representativeness or content relevance of the elements or items for a questionnaire'*.[323] In other words, it can be described as *'the degree to which elements of an assessment instrument are relevant to and representative of the targeted construct for a particular assessment purpose'*.[322] An investigation into the content validity of a questionnaire such as ASAT v15a involves establishing its relevance and representativeness to the targeted construct.[234] The relevance component refers to the instrument's appropriateness of its elements and function of assessment for the targeted construct.[322] In terms of ASAT v15a, its relevance to hospital-based ASPs will be demonstrated if the domains and questions are appropriate for measuring ASPs and also if the ASAT possesses the ability to accurately analyse ASPs in hospitals.

3.2. Aim

- To investigate the content validity of ASAT v.15a

3.3. Objectives

- To determine the content validity of the ASAT by acquiring *'think aloud'* data from antimicrobial pharmacists
- To modify ASAT v15a using the findings from the cognitive interviews in order to produce ASAT v16

3.4. Participant demographics

3.4.1. Demographics of antimicrobial pharmacists

Hospital-based AMPs were the target staff group for this study. This staff group were chosen because they have antimicrobial stewardship as part of their job description. A total of eight antimicrobial pharmacists were recruited and cognitive interviews were conducted with each pharmacist. Two male and six female antimicrobial pharmacists participated in this study with an age range between 28 to 45 years. These pharmacists were employed by their NHS Trusts *(see section 3.4.2)* as antimicrobial pharmacists from a period of one year to seven years.

3.4.2. Demographics of NHS Trusts and respondents

The demographics of the NHS Trusts which participated in study 1 are given in table 3.1 (below).

Table 3.1- The types of NHS Trusts included in Study 1[324]

Respondent number	Trust type	Number of antimicrobial pharmacists	Number of years in AMP post	Number of beds
1	Foundation Acute	1	5	1121
2	Foundation Acute	2	1	891
3	Foundation Acute	1	3	728
4	Foundation Acute	1	3	917
5	Acute	1	4	617
6	Foundation Acute	1.5	7	513
7	Foundation Acute	1	2	252
8	Foundation Acute	1	5	504

Nb. These data were collected during Study 1. The number of beds and years in a antimicrobial pharmacist post were accurate as of March 2011

3.5. Methods

Qualitative data were obtained from respondents using cognitive interviews. Cognitive interviews are in-depth interviews which focus on the mental or cognitive processes that respondents use to answer survey questions *(see section 2.2.10.2)*. A total of eight AMPs were interviewed for this study. These AMPs had an age range between 28 to 45 years and were employed by their hospitals as antimicrobial pharmacists for between 1 and 7 years *(see table 3.1).* Respondents were asked to *'think aloud'*, that is, to verbally express their thought processes as they generated responses to each question in ASAT v15a. Each interview was digitally recorded and transcribed verbatim.

Data analysis was conducted on the transcribed interviews using a thematic framework *(see section 2.2.10.7)* based on the Four Stage Model *(see section 2.2.10.5.1)* and also Flexible Processing Model for survey interaction *(see section 2.2.10.5.2)*.

3.6. Results

The results of study 1 have been categorised into the four sub-processes of survey interaction which are comprehension, decision/judgement, information retrieval, and response formatting. The results have been presented at a question level, in other words, each question where respondents have highlighted a cognitive difficulty will

be discussed. The reported cognitive difficulties provided the basis for further revisions to the ASAT. Also, other findings which may not be directly associated with the survey interaction process but are still pertinent to further iterations of the ASAT v15a, will be discussed. These findings include question duplication, double-barrelled questions, irrelevant key concepts/questions, ASAT scores and weightings and respondents' general feedback on ASAT v15a will be discussed.

3.6.1. Comprehension (question encoding) problems

27/83 questions were reported by respondents to contain comprehension problems. Respondents were unable to encode some questions due to the presence of vague or ambiguous concepts and unfamiliar terms or terminology. There were wide variations in the way respondents interpreted the question intent of individual questions. Consequently, comprehension (question encoding) problems resulted in the respondents' inability to process information beyond the comprehension phase.

3.6.1.1. Comprehension-Lexical problems

Lexical problems were found in 5/83 questions. Lexical problems are associated with respondents' understanding with the meaning and use of words within the question *(see table 2.4)*. These types of problems are evidenced by respondents' tendency to indicate that they do not understand the word meaning within the context that it is used within a question. In this analysis, the meaning of the word(s) or phrase(s) refers to the *'core'* or *'central'* meaning. Lexical problems occur when there is a disparity between the developers' intent and the respondents' interpretation of the question. This disparity can occur at word level, phrase level or question level.

Table 3.2 - Question 1.1(ASAT v15a)

No.	Question
1.1	**Does the Trust have a written strategy for assuring the quality of antimicrobial use?**

In response to Q1.1 *(see table 3.2)* the phrase *'written strategy for assuring the quality of antimicrobial use'* prompted a number of interpretations by respondents. They indicated that an antimicrobial strategy would be addressed in several documents as opposed to a single standalone document. Strategies for assuring the quality of antimicrobial use could be included in documents produced by other

committees such as the infection control committee and the antimicrobial stewardship or management committee. One respondent commented *'I think that this can be open to interpretation, 'assuring the quality of antimicrobial use' it depends on what you want to ask. What do you mean by strategy? The definition of 'strategy' would need interpretation because it relates to assuring the quality of antimicrobial use and this can be open to interpretation. We have a strategy for the antimicrobial team, and we have given the team aims and objectives. People may start to think about the quality of antimicrobial use for example compliance, costs constraints'* (AMP 5). Also, the written strategy was interpreted as the antimicrobial prescribing policy, one respondent commented, '*we have an antimicrobial prescribing policy which is a strategy if you like on how we would ensure that we use antimicrobials appropriately as opposed to the antimicrobial guidelines which are specific for infections… so I say yes'* (AMP 7).

Table 3.3 - Question 1.8 (ASAT v15a)

No.	Question
1.8	**Does the Trust Board including non-Exec directors receive an annual report pertaining to AM Stewardship?**

In response to Q1.8 *(see table 3.3)*, respondents indicated that they were unsure whether the *'annual report pertaining to antimicrobial stewardship'* should focus on prevalence data only. For example, respondents were unsure whether a report containing their hospitals' incidence of *C.difficile* or MRSA statistics or an audit report on antimicrobial prescribing should be included in an annual report. One respondent commented, *'there will be a component of the infection control report it goes to Exec Board but I am not sure about the specifics on antimicrobials. It is high on the agenda because we have all directorates undertake a point prevalence audit'* (AMP 6).

Most hospitals indicated that they were unable to report whether the Trust Board received an annual report pertaining to antimicrobial stewardship for example, if the report goes to the Infection Control Committee which has members who sit on the trust board, could they answer yes to this question? One respondent commented '*yes I know who to send them to, for example, to infection control committee but there are people who sit on that who are part of the exec but I don't know if that*

would come under the flag of trust Board [pause] *We do have exec members who sit on that so I would need clarification about that'* (AMP 3).

Table 3.4 - Question 2.12 (ASAT v15a)

No.	Question
2.12	**Is selection for the guidelines informed by local microbiological sensitivity patterns?**

Most respondents indicated that they had difficulty in understanding the meaning of the phrase *'selection for the guidelines informed by local microbiological sensitivity patterns'*. In response to Q2.12 *(see table 3.4),* one respondent stated that, *'This question is a bit confusing and it would need further clarification. It is the way that the question is worded,* (respondent rereads question 2.12), *what do you mean? Do you mean selection for the antimicrobial choice or do you mean are the choices recommended in the guideline consistent with the local sensitivity patterns'.* (AMP 5) Respondents suggested that this question should be rephrased to clarify whether the question intent refers to the antimicrobial guideline recommendations or to the antibiogram results reported by microbiology.

Table 3.5 - Question 3.5 (ASAT v15a)

No.	Question
3.5	**Is the safety of AMs linked to incident reporting with feedback and action plans?**

Other phrases such as *'safety of antimicrobials linked to incident reporting', 'antimicrobial prescribing policy'* and *'substantive post'* were difficult to interpret by respondents. For example, in Q3.5 *(see table 3.5)*, within the phrase *'safety of antimicrobials linked to incident reporting',* the word *'linked'* appeared to be the trigger for the misinterpretation of this phrase. One respondent commented, *'Safety of antimicrobials linked to incident reporting? What does that mean exactly? What does it mean by linked? Do they mean that antimicrobial incident reporting should be linked into the antimicrobial stewardship group?'.* (AMP 7) Respondents appeared to misunderstand the purpose of the term *'linked'* as it is used in this question. They seemed to view this term as signposting them to produce antimicrobial incident or safety reports but they did not understand whether these reports should be sent to specific departments or the AMS group only. The question intent of Q3.5 is to examine whether hospitals have a system for recording and reporting antimicrobial

associated incidents. The reports should be feedback to the relevant departments and the antimicrobial stewardship committee.

Table 3.6 - Question 4.2 (ASAT v15a)

No.	Question
4.2	**Is compliance with AM prescribing Policy audited and fed back in each specialty at least once a year?**

In response to Q4.2 *(see table 3.6)*, respondents indicated that they viewed the *'antimicrobial prescribing policy'* as a distinct document, which is separate to the *'antimicrobial policy'* such as the antimicrobial formulary. One respondent commented,

'So I'm assuming … because the wording is quite confusing here, because of 'antimicrobial prescribing policy' [pause] *do they mean the formulary in terms of prescribing or prescribing against the policy in terms of stop dates or review dates. It may be worth clarifying. I mean we do feedback to each specialty at least once a year and sometimes more because of the point prevalence studies. The junior doctors have presented to high level infection control committees etc. so we do at least yearly and we do audits against stop dates, review dates and allergy status.'* (AMP 4)

This verbal report indicated that the respondent had interpreted *'antimicrobial prescribing policy'* as the *'antimicrobial formulary'*, which was not the intended interpretation of Q4.2. This question aims to examine if compliance antimicrobial policy is audited annually within each specialty. Most respondents indicated that they conduct point prevalence audits annually so therefore they were able to answer *'yes'* to this question. However, it was unclear whether this question refers to an annual point prevalence audit or to other audit activity.

3.6.1.2. Ambiguous or vague terminology

Comprehension/Lexical problems *(see table 2.4)* were not the only type of comprehension problems highlighted from the verbal reports. On analysis of the verbal reports, respondents indicated that the presence of vague or ambiguous terminology were present in 21/83 questions. This resulted in the scope of these questions being undetermined by respondents. These types of problems are known as inclusion/exclusion problems where respondents interpret word(s) or phrase(s) in

numerous ways due to the presence of ambiguous or vague terminology within questions. Consequently, respondents are uncertain of the question content and are unable to encode the question correctly. Inaccurate interpretations negatively impacted the response accuracy and introduced measurement error into the instrument.

The term *'policy'* is used numerous times within the ASAT. On analyses of the verbal reports, the term *'policy'* was understood by the respondents however they indicated that this word triggered multiple interpretations. The term *'antimicrobial policy'* relates to the standards of prescribing practice however it was interpreted by respondents as the *'antimicrobial guidelines'* or the *'antimicrobial formulary'*. Antimicrobial guidelines refer to the recommended treatment or surgical prophylaxis guidelines. Antimicrobial formulary refers to the limited list of antimicrobials used for the treatment of infections.

Table 3.7 - Question 2.1 (ASAT v15a)

No.	Question
2.1	**Is there an AM Policy (overall principles for use) or section in another Trust Policy?**

In response to Q2.1 (see table 3.7), respondents commented, *'when you have the word policy in there that's when it becomes difficult because we have antimicrobial guidelines which comes out of your antimicrobial strategy* (respondent rereads question). *You have your strategy document and then you have your guidelines...I am not sure that we can say we have an antimicrobial policy. A guideline is there for guidance and policy is mandatory* [pause] *the wording is confusing.'* (AMP 6). Also, interviewee 2 responded, *'Yes there is an antimicrobial formulary, it is quite comprehensive but I wouldn't say that it is the most accessible.'*

Within the context of the information given to patients, carers and the public, the term *'policy'* was interpreted the infection control policy for *C.difficile* and MRSA or a hospital's policy on medicines information.

Table 3.8 - Question 7.1 (ASAT v15a)

No.	Question
7.1	**Is there a policy for providing information on AMs to patients?**

In response to Q7.1 *(see table 3.8)*, respondents commented,

'*We have a policy for C.difficile and MRSA, so if the policy is referring to antimicrobials, I would honestly answer the question as no* [pause] *but if you are saying if there is anything in place from an infection control point of view then the answer to that would be yes because there is guidance on C.difficile and MRSA. But there is no specific guidance on pneumonia or something like that'* (AMP 2). This respondent indicated that they interpreted the word *'policy'* for patient information as the guidance contained within the *C.difficile* and MRSA policies on patient information. However, there were no patient information guidelines for other types of infections. Another AMP commented,

'At first I was reading Q7.1, I was thinking if we have an info leaflet, or is there a policy? I'm not sure what they mean? Not sure why that would be relevant, any drug you give out may be given counselling. I'm not sure if there's a document that specifies what the patient should be told is necessary [pause] *It's done on an ad hoc basis. We are all professionals as well so we give out counselling'* (AMP 3). Respondents indicated that they may have a general policy for the information on medicines given to patients, but this policy is not specific to antimicrobials. Also, some respondents indicated that since patient information leaflets are given to patients with their medication that a patient information policy may not be necessary.

Table 3.9 - Questions 2.3 to 2.5 (ASAT v15a)

No.	Question
2.3	**Is there a system for control of entry for new AMs?**
2.4	**Is there a system for restricted access to certain Formulary AMs within the Trust?**
2.5	**Is there a system for reporting unauthorised prescribing?**

The term *'system'* is used in the ASAT in different contexts in order to identify the mechanisms hospitals use to control entry of new antimicrobials (Q2.3), restrict access to formulary antimicrobials (Q2.4) and to report unauthorised prescribing (Q2.5). In response to these three questions, respondents indicated that they encountered difficulties in interpreting the term in the contexts that it was used. In response to Q2.3 *(see table 3.9)*, respondents indicated that they were numerous methods used to restrict antimicrobials such as codes, passwords, microbiology pre-approval and a restricted list of antimicrobials. In response to Q2.4 *(see table 3.9)*,

the phrase *'system for restricting access'* proved difficult for respondents to interpret for example one respondent commented,
'*What do you mean? System for restricted access?* [pause] *There is a restricted section in the formulary however some trusts have codes to get things out of pharmacy and passwords; we don't have anything like that here. I would like to say that if someone prescribed a restricted drug and it was out of hours then we would follow it up the next day. But generally within the trust we don't get people prescribing outside of the formulary and we don't have as many restricted antimicrobials as other trusts'* (AMP 2).

The terms *'system'* and *'unauthorised prescribing'* triggered a number of interpretations and are both examples of conceptual variability. In response to Q2.5 *(see table 3.9)*, one respondent commented,
'… no I suppose not… but I am not sure what that would entail really [pause] *I don't understand what 'system' means. Well,* [pause] *I would like an example... because I can't imagine what it means for example, who you would be reported to and what sort of system it would be* [pause] *that would be helpful. It also makes me think of what I should be doing it and what that system should be like'* (AMP 7). One AMP viewed the *'system'* as the antimicrobial ward round as opposed to a dedicated, formularised reporting system such as a hospital incident reporting system (HIRS).
'We do antimicrobial ward rounds so we could refer them for review, but would that be the same thing as reporting. For me reporting is just like recording and producing a list of all the inappropriate prescribing whereas we get it referred to the ward round. When I think of a reporting system I think of an adverse event reporting system so we do have ways of reviewing unauthorised prescribing but we don't a system for recording them. I wouldn't be quite sure how to answer that one [pause] *if yes or no'* (AMP 3). The question intent of Q2.5 is to identify the mechanisms which hospitals use to report unauthorised prescribing however it appeared that respondents were unable to interpret the question as intended. They indicated that a clear definition of system is required to aid the comprehension of these questions. Respondents were unsure of what to consider as *'unauthorised prescribing'*, and questioned whether this term related to prescribing to non-formulary antimicrobials (AMP 4), restricted antimicrobials without microbiology approval (AMP 4) or non-compliance to formulary (AMP 8). Respondents commented,

'So I am assuming that means [pause] *just looking at the question I assume that means non-formulary prescribing or prescription of restricted antimicrobials without prior approval. Again, I think that the question can be worded better. But yes we do have an incident reporting system.'* (Interview 4)

'*What do you class as unauthorised prescribing? Are you looking at prescribing drugs that are non-formulary or a restricted antimicrobial that has been used in hospital for example meropenem for CAP, we allow meropenem and we treat CAP but that would be unauthorised prescribing because meropenem is restricted and only certain people are allowed to prescribe that. Or is it just that you have CAP but the patient has a CURB score of 1 and they are not particularly ill and have been blasted with all the antimicrobials under the sun* [pause] *you have different levels of unauthorised prescribing but it is unclear which one you are measuring there*' (AMP 8).

Respondents indicated that the phrase *'unauthorised prescribing'* needs to be clearly defined to enable consistency in the interpretation of this phrase by end-users.

Table 3.10 - Questions 2.6 to 2.7 (ASAT v15a)

No.	Question
2.6	**Are peer-reviewed, evidence-based, guidelines available for treatment of common infections?****
2.7	**Are peer-reviewed, evidence-based, surgical prophylaxis guidelines available for the common procedures?**

The phrases *'common infections'* and *'common procedures'* were viewed as ambiguous by respondents, in Q 2.6 and Q2.7 respectively *(see table 3.10)*. They indicated that they would need clarification on the infections that should be included in these phrases. One respondent commented, *'You may need to clarify what you mean by common infections so you could ask, 'do you have guidelines for all these things? Whether you would have a list of what you would classify as common infections, and do we cover them all?'* (AMP 2). In 2005, the Specialist Advisory Committee on Antimicrobial Resistance (SACAR) produced standards for antimicrobial polices which gives a list of common infections. [325] This document will be included within the glossary of the ASAT in order to clarify which infections are classed as common infections and common procedures. Respondents indicated that they were unsure how to answer Q2.7, because their hospitals did not perform all of

the common procedures as stipulated by the SACAR template. One respondent commented,

'Again, it would just depend if it is for the majority of procedures…In our hospital the common ones are orthopaedics but we don't have them for everything. I suppose if you have 1 point for 50% of things... points should be allocated to the percentage of procedures covered' (Interview 3). Another respondent commented *'Surgical prophylaxis is probably different because each trusts would have different specialties.... It might be a bit different.'* (AMP 2)

These comments indicate that guidance is required on how to answer Q 2.7 for hospitals that do not perform each common procedure as stipulated by SACAR.

Table 3.11 - Question 2.21 (ASAT v15a)

No.	Question
2.21	**Are there antimicrobial ward rounds?**

In Q2.21 *(see table 3.11)*, the phrase *'antimicrobial ward round'* was understood by respondents however respondents indicated that they were unable to decide what constituted an antimicrobial ward round. For example, is a ward round considered an *'antimicrobial ward round'* because an antimicrobial pharmacist is involved? One respondent commented, '*Just saying antimicrobial ward rounds isn't specific, I think that what you are asking is...is there a multidisciplinary ward round with microbiology and pharmacy? Does it go to review difficult patients? For example, you could class other ward rounds as antimicrobial ward rounds because the antimicrobial pharmacist is involved, the ICU consultant would review their patients every day'* (AMP 8).

Respondents stated that antimicrobial ward rounds were conducted in areas such as critical care, intensive care units (ITUs) and haematology but not in non-critical wards. One respondent commented

'*Ward rounds probably need defining a bit more because our ward rounds here are very good but how they work is the intensive care areas of which we have three, we have daily ward rounds and the rest of the hospital have then twice a week at the minute but we are going to four times a week in September but the most critically ill patients for example ICU, AICU, transplant ICU and neonatal ICU have daily ward rounds all the time. Maybe you need to specify do want the answer to any ward*

round or to critical areas, and also who you want to be on those ward rounds. Because the ones on ITU, the microbiologist does on their own with the teams that work on those wards, the ones to the rest of the hospital I go on' (AMP 2). The composition of the antimicrobial ward round requires clarification because all trusts will have ward rounds but the composition will differ.

Table 3.12 - Questions 4.9 to 4.10 (ASAT v15a)

No.	Question
4.9	**Is antimicrobial consumption reported to clinical specialties?**
4.10	**Is attendance at audit feedback meetings recorded?**

Most respondents indicated that they understood the question intent of Q4.9 *(see table 3.12)*. However, they were uncertain whether the question referred to all antimicrobials or trust identified key restricted antimicrobials only. One respondent commented, '*Vague, some people would identify key antibiotics and that is what they would report which is probably acceptable but would need clarification'* (AMP 1).
In response to Q4.10 *(see table 3.12)*, the phrase *'audit feedback meetings'* was viewed as a meeting that is separate from normal clinical audit meetings. Respondents indicated that they viewed this audit meeting as a meeting that was dedicated to antimicrobial-related audits only. One respondent commented, *'No, but it depends on what you mean by audit feedback meetings because we feedback our audits to the antimicrobial committee and they would be recorded and there would be minutes. But are we looking at a specific antimicrobial audit feedback meeting, in which case we don't have those'* (AMP 2). Respondents interpreted this meeting maybe a dedicated antimicrobial feedback meeting where antimicrobial prescribing or compliance audits were discussed and feedback to specific staff groups.
The other issue raised by respondents in response to Q4.10 was whether the recorded attendance referred to antimicrobial pharmacists only or to other staff groups. One respondent commented, *'I would need clarification for this question. What does this question mean? Which staff groups are you referring to? Is it the attendance of the antimicrobial pharmacists to report on audits?*' (AMP 5) They also questioned what would be the role of the antimicrobial pharmacist in attending these types of meetings.

Table 3.13 - Questions 5.1 to 5.18 (ASAT v15a)

No.	Question
5.1	**Is there an AM Education and Training Strategy?**
5.2	**Do all AM prescribers receive printed information about AM prescribing, formulary and guidelines at induction?**
5.3	**Do all pharmacists receive printed information about AM prescribing, formulary and guidelines at induction?**
5.4	**Is an annual update in safe and effective AM prescribing mandated for all prescribers?**
5.5	**Is an annual update in safe and effective AM prescribing available for all prescribers?**
5.6	**Is an annual update in safe and effective AM prescribing mandated for all pharmacists?**
5.7	**Is an annual update in safe and effective AM prescribing available for all pharmacists?**
5.8	**Is an annual update in safe and effective AM prescribing mandated for all staff who administer AMs?**
5.9	**Is an annual update in safe and effective AM prescribing available for all staff who administer AMs?**
5.10	**Do all staff who prescribe AMs receive annual training in safe and optimal use?**
5.11	**Do all staff who administer AMs receive annual training in safe and optimal use?**
5.12	**Do all staff who dispense AMs receive annual training in safe and optimal use?**
5.13	**What proportion of Foundations Year doctors attend training on safe and effective AM prescribing?**
5.14	**What proportion of registrars/specialist trainees attend training on safe and effective AM prescribing?**
5.15	**What proportion of consultants attend training on safe and effective AM prescribing?**
5.16	**What proportion of NMPs attend training on safe and effective AM prescribing?**
5.17	**What proportion of staff who administer AMs attend training on safe and effective AM prescribing?**
5.18	**What proportion of clinical pharmacists/technicians attends training on safe and effective AM prescribing?**

Section 5 *(see table 3.13)* of the ASAT examines the strategies which trusts use to educate and train antimicrobial prescribers on AMS. Respondents indicated that this section was the most difficult to understand. Respondents indicated that they did not understand the phrase *'training and education'*. Respondents indicated that they were unable to answer section 5 because they interpreted *'training and education'* as a structured, formal Infection management module for foundation year doctors (AMP 2), informal sessions for doctors which are usually triggered by AMR outbreaks or newly published guidelines or evidence (AMP 2) and infection control training for nursing staff (AMP 3).

Some respondents indicated that they do provide formal infection management training for newly employed doctors however they were unsure of the content of the training programmes for nursing staff. In response to Q5.1, one respondent commented, '*Not to my knowledge but it would depend on who we are looking at training so maybe it needs to specify who we are training. The junior doctor's training is very structured because it always takes place. The nurses get a more infection control training than antimicrobial training because they don't prescribe, within pharmacy it is more ad hoc'* (AMP 2).

Respondents indicated that training and education is mandatory for newly employed prescribers at induction however continuing education is quite sporadic and not compulsory. One interviewee commented '*we do training for all the junior doctors on a regular basis (annually) but the middle grades and consultants are not part of the mandatory session'* (AMP 8).

Respondents indicated that they may provide informal educational sessions for doctors however these sessions would be triggered by AMR outbreaks and newly published guidelines. Also, they indicated that they were unclear of the ASAT's definition of antimicrobial educational updates and the content of the updates. One respondent commented '*I don't understand what they want but what would they like the update to include?* (AMP 4) Respondents stated that trusts may have an e-prescribing module that included aspects of prudent antimicrobial prescribing however these modules are not always comprehensive. Also, respondents commented that they were unable to distinguish between the phrases '*safe and effective antimicrobial prescribing'* and *'safe and optimal use'* of antimicrobials. They indicated that Q5.4 to Q 5.9 and Q 5.10 to Q5.12 appear to be measuring similar (overlapping) areas of prudent antimicrobial prescribing.

Respondents indicated that they were unsure which staff group(s) that Q5.12 and Q5.18 referred to. Dispensing of antimicrobials was carried out by a number of staff groups within hospitals such as pharmacy technicians or A&E staff. One AMP commented,

'*Do you mean the pharmacy technicians? I do updates with the pharmacy technicians as well; it's not like mandatory training. They have weekly meetings so often I would go in and tell them about antimicrobials. So I could probably answer yes. I would say training 'no' but updates 'yes'. What is the difference between update and training? Training sounds like it something you would need to be signed*

off for to show that you were competent, I'm not sure that they would need that' (AMP 3).

In response to Q5.18, one respondent commented, *'Do you mean clinical pharmacists and technicians or do you mean clinical pharmacists only or technicians only because the percentage would be quite different...we run regular sessions for pharmacists, a handful would attend, but if you included the techs as well the proportion would be half. You may need to ask it as two different questions or put clinical pharmacists and technicians'* (AMP 8). The misinterpretation of this question could lead to reporting of training to the incorrect staff groups (measurement error) especially if there is misinterpretation by end-users.

Table 3.14 - Question 6.7 (ASAT v15a)

No.	Question
6.7	**Does the lead AMP have written objectives within the last year?**

Respondents were able to generate a response to Q6.7 *(see table 3.14)* however there were unsure whether to include their general written objectives or objectives that are solely linked to their trusts' ASPs. One respondent commented, '*Is that in relation to our job or in relation to what we should be doing?* [pause] *Yes, because we all have objectives, that is, I know what I need to do… put it that way. I think it should be more 'does the antimicrobial pharmacist has written objectives that are linked in with the antimicrobial plan or the infection control plan for the year? The antimicrobial pharmacist will have written objectives not necessarily linked the trust's antimicrobial strategy'* (AMP 2).

Table 3.15 - Question 7.2 (ASAT v15a)

No.	Question
7.2	**Are patients or their legal guardian usually (>80% of the time) informed that they have been prescribed an AM and the reason why an AM is necessary?**

Also, respondents indicated that they were unsure of which staff groups this question was targeted. One respondent commented, *'By whom? By the doctors, nurses or pharmacists?'* (AMP 5). This question posed two main difficulties for respondents, firstly, they were unable to map a response to the response options given and also they were uncertain to the target staff group for Q7.2 *(see table 3.15)*.

Table 3.16 - Question 7.5 (ASAT v15a)

No.	Question
7.5	**Are patients or their legal guardian usually informed of the course length and the importance of finishing the course?**

In response to Q7.5 *(see table 3.16)*, respondents interpreted the phrase *'informed of the course length'* as the information provided on the prescription box. One respondent commented '*Yes, I would guess 100% we would have the info on the side of the box, but you have MAU and A&E patients who get pre-packs on discharge… so I couldn't answer that'* (AMP 3). They indicated that they would be confident in answering this question for hospital in-patients however in departments such as medical assessment units (MAU) and A&E they were unsure if they could assign a score of 100% *(see above comment- AMP 3)*. They assumed that patients would receive counselling from prescribers about the antimicrobials that they have been prescribed. Counselling would include information on course length as well as other aspects antimicrobial chemotherapy such as route, duration and frequency. Also, respondents believed that most patients within their hospitals would receive counselling on the importance of finishing a course of antimicrobials.

3.6.1.3 Comprehension-computational problems

Another type of comprehension problem was identified on analysis of the verbal reports. This type of comprehension problem is known as computational problems and occurs in instances where questions require difficult mental calculations or manipulation of data for response generation. Respondents reported that comprehension-computational problems occurred in one question.

In response to Q7.2 *(see table 3.15)*, respondents indicated that it would be very difficult to calculate the number of patients who received counselling on the reason why an antimicrobial was necessary. This calculation for this question requires the respondent to calculate, whether '*>80% of the time'* a patient has been informed that have been prescribed an antimicrobial and the reasons why an antimicrobial is necessary and choose a response from 3 = >80%, 2 = 50% -79%, 1 = 30% - 49% or 0 = <30%. The calculation of '*>80% of the time'* was very difficult to quantify by respondents because they were unsure of the denominator and numerator required for this calculation. It was not possible to map '*>80% of the time'* onto the given

response options. This type of problem is a comprehension-computational problem, where respondents are unable to calculate an answer from the given response options.

Misinterpretation of terms and phrases can result in questions be being interpreted as measuring similar concepts. This could potentially lead to respondents viewing these questions as duplications, which will be discussed in a subsequent section of this chapter *(see section 3.10.1)*.

3.6.2 Information retrieval problems

Respondents reported information retrieval problems in 10/83 questions. The analysis of the verbal reports indicated that information retrieval problems were primarily caused by incomplete or incorrect question encoding *(see section 3.6.1)* during the comprehension phase. This resulted in respondents' inability to start the information retrieval phase of the survey interaction process. The two main reasons were reported by respondents were either they were unable to recall the information required to answer the question, sometimes reported as *'I cannot remember*' or they were uncertain of the answer of the question, sometimes reported as *'I do not know'*. In both instances, respondents indicated that they would have to verify the information requested by the ASAT by accessing other data sources such as the training packages for nursing staff. There were very few information retrieval problems of this type reported by respondents because generally they were able to report factual information about their hospitals' ASPs. However, these data could not be verified by the researcher.

Table 3.17 - Question 2.16 and question 3.1 (ASAT v15a)

No.	Question
2.16	**Does the AM policy stipulate that prescriptions for AMs be reviewed in line with 'Saving Lives'?**
3.1	**Does the Trust have guidelines that include advice for managing patients with AM allergies?**

Respondents indicated that they were unable to recall the information necessary to answer Q2.16 and Q3.1 *(see table 3.17)*. In response to Q2.16, respondents indicated that they were unable to recall the content of Saving Lives, which provides guidance on the review frequency for antimicrobial prescriptions. However, they

indicated that if they were able to access Saving Lives, they will be able to answer this question. One respondent commented,

'I can't remember [pause] *I am sure that in our policy that it refers to Saving Lives* [pause] *I can't remember* [pause] *I guess* (respondent reads scoring) *so it's saying how often?* [pause] *maybe change the wording of that question to instead of in line with Saving Lives change the question to …how often are prescriptions for antimicrobials reviewed?' I don't know off the top of me head what our policy says or what it stipulates regularly or every day?*' (AMP 7).

In response to Q3.1, each respondent indicated that they did not have a stand-alone antimicrobial allergy guideline. Respondents indicated that guidelines on managing patients with allergies may be covered in an overarching trust policy. One respondent commented,

'It would have an anaphylaxis policy, not really just for antimicrobials, we have written ones before. I would have to double check. The question is quite clear [pause] *for all drugs but not just for antimicrobials. People would have something about penicillin allergy* [pause] *so won't know how to answer that question'* (AMP 3).

Respondents indicated that in order to answer Q3.1 they would need to verify whether antimicrobial allergies were covered in their hospitals' policy.

Table 3.18 - Questions 1.3, 5.11, 5.13, 5.15, 5.16, 7.1 and 7.2 (ASAT v15a)

No.	Question
1.3	**Does the DIPC have antimicrobial stewardship included within their job description?**
5.11	**Do all staff who administer AMs receive annual training in safe and optimal use?**
5.13	**What proportion of Foundations Year doctors attend training on safe and effective AM prescribing?**
5.15	**What proportion of consultants attend training on safe and effective AM prescribing?**
5.16	**What proportion of NMPs attend training on safe and effective AM prescribing?**
7.1	**Is there a policy for providing information on AMs to patients?**
7.2	**Are patients or their legal guardian usually (>80% of the time) informed that they have been prescribed an AM and the reason why an AM is necessary?**

Respondents indicated that they were not knowledgeable about their hospital practice as it related to Q1.3, Q5.11, Q5.13, Q5.15, Q5.16, Q7.1 and Q7.2 *(see table 3.18).*

In response to Q1.3, respondents indicated that they were unaware of the content of their DIPC's job description. One respondent commented, '*I have no idea, the DIPC for this hospital is director of nursing for the hospital and I have never seen her job description and I don't think anyone else has'* (AMP 8). They reported that the DIPC would attend the antimicrobial committee meeting so they assumed that antimicrobial stewardship is part of the job description. However, they were unsure whether the duties related to antimicrobial stewardship were mandatory or optional. One interviewee commented, ''*I haven't read her job description but she attends the antimicrobial stewardship committee meetings so if it isn't in her job description she is doing it* [pause] *I would say that she is a member if the antimicrobial stewardship group but I wouldn't know if it is in her job description. I could go away and check that… but I'm not sure that is good use of my time when completing this tool'* (AMP 7).

Respondents indicated that they would be uncomfortable requesting the job description from the DIPC because they are usually a senior member of staff. One respondent commented, *'I wouldn't feel comfortable asking for her job description and at some hospitals it is the Chief Exec...quite high level'* (AMP 8). Also, they suggested that it would be difficult for the antimicrobial pharmacist to access the job description. One respondent commented, *'If this questionnaire is going to be given to an antimicrobial pharmacist or someone else who is not the DIPC to complete, it would be difficult to get hold of the job description'* (AMP 5).

Respondents indicated that they were not aware of the content of the training packages for staff who administer antimicrobials therefore they were unable to answer Q5.11. One respondent commented,

'I need to see what training the nurses receive but what they do for drug administration. I would have to check to see if that was enough or should it be more tailored to antimicrobials. Information we are required to give on any drug for example administration of IVs etc. and reconstitution, if they want you to do something more specific [pause] *well I would be lying* [pause] *we do a general one* [pause] *What specific info would the nurses need because it is an antimicrobial?'* (AMP 3). They suggested that this staff group may receive training on the general administration of drugs but this may not be specific to antimicrobials.

Respondents indicated that they were unsure of the percentage of foundation year doctors who attended training on safe and effective antimicrobial prescribing. In

response to Q5.13, one respondent commented, *'I'm sure we could find it out but it couldn't answer for the top of my head. I could check with the girl who coordinates all the teaching sessions because they keep registers and she could give me those figures'* (AMP 3). Additionally, in response to Q5.15, Q5.16, Q7.1, Q7.2 similar responses were given by respondents where they indicated that they would need to check and verify the data required for these questions.

3.6.3 Judgement/Decision problems

Respondents reported judgement/decision problems in 6/83 questions. Judgement/Decision problems were primarily caused by the absence of guidance on the time period that should be applied by trusts when conducting an ASAT evaluation. Consequently, this resulted in temporal (judgement/decision) problems being reported by respondents in 4/6 questions.

3.6.3.1 Temporal problems

In response to Q1.1 *(see table 3.19)* respondents did not understand whether the question as referring to past, current or future planned prescribing practice.

Table 3.19 - Question 1.1 (ASAT v15a)

No.	Question
1.1	**Does the Trust have a written strategy for assuring the quality of antimicrobial use?**

One respondent commented, *'Am I answering in terms of what currently happened in the trust?'* (AMP 4). Subsequently, the respondent decided to answer the question according to current trust practices after rereading the question.

Table 3.20- Questions 5.13 to 5.14 (ASAT v15a)

No.	Question
5.13	**What proportion of Foundations Year doctors attend training on safe and effective AM prescribing?**
5.14	**What proportion of registrars/specialist trainees attend training on safe and effective AM prescribing?**

Respondents indicated that Q 5.13 and Q5.14 *(see table 3.20)* were difficult to answer because they were unsure whether these questions were referring to training at induction or continuing education. They reported that most trusts have an

infection management component as part of their induction programme for newly recruited doctors. However, there was no formalised ongoing education on prudent antimicrobial prescribing for doctors who are currently members of staff such as middle grades and consultants. In response to Q5.14, one respondent commented, *'Again, it's mandatory on induction...but not if already in post'* (AMP 4) and another respondent commented, '*if we are talking about newly inducted grades of staff there would be a proportion but I wouldn't know what it is. If we are talking about existing staff like SpRs and specialist trainees then the answer would be zero. I was going to say that one of our infectious disease consultants have done a session at the weekly Grand Round. Again we wouldn't have figures for that...but some would have attended* [pause] *Consultants* [pause] *zero'* (AMP 7).

Table 3.21 - Question 6.4 (ASAT v15a)

No.	Question
6.4	**Does the lead AMP have >3 years experience in this specialist role?**

Respondents were unsure if this question referred to the either previous experience prior to starting post at their hospital or the time in current post due to the lack of a specified time reference period for an ASAT evaluation, in response to Q6.4 *(see table 3.21)*. One respondent commented, '*Does that mean from recruitment or currently? I do now; if I answered this a year ago I would answer no'* (AMP 3). Another type of judgement/decision problems was identified on analysis of the verbal reports. This type of problem could be classified as computational problems where respondents reported their inability to determine the appropriate numerator and/or denominator required to calculate an answer to the questions as required. Computational (judgement/decision) problems were reported by respondents in 2/6 questions.

Table 3.22 - Question 5.18 (ASAT v15a)

No.	Question
5.18	**What proportion of clinical pharmacists/technicians attends training on safe and effective AM prescribing?**

In response to Q5.18 *(see table 3.22)*, which examined the proportion of clinical pharmacists or technicians who attended training on safe and effective prescribing, respondents indicated that they were unable to answer this question. They viewed

this question as asking about two distinct staff groups, that is, clinical pharmacists and pharmacy technicians. This implied that there were two potential numerators and denominators for this question. One respondent commented,
'Do you mean clinical pharmacists and technicians or do you mean clinical pharmacists only or technicians only because the percentage would be quite different [pause] *we run regular sessions for pharmacists a handful would attend but if you included the techs as well the proportion would be half. You may need to ask it as two different questions or put clinical pharmacists and technicians.'* (AMP 8)

3.6.3.2 Computational problems

Respondents reported that the calculation required for Q6.3 *(see table 3.23)* was very complex. This question asks hospitals about the proportion of whole time equivalent (WTE) pharmacy staff per 500 beds that spend time on antimicrobial duties.

Table 3.23 - Question 6.3 (ASAT v15a)

No.	Question
6.3	**What WTE AM Pharmacy staff/500 beds are spent on antimicrobial duties?**

Respondents indicated that they experienced difficulty in determining the correct numerator required for answering to this question. They queried which members of their hospitals' pharmacy staff should be included in the calculation. One respondent commented, *'Ok interesting* [pause] *so it's pharmacy staff, so they are accounting for technicians etc.? Maybe it needs to clarify or define whole time equivalent pharmacy staff for example specialist technicians with antimicrobial duties'* (AMP 1). Also, respondents queried how they would account for part-time staff with antimicrobial duties. One interviewee commented,
'*That's quite difficult to work out. I find that very hard to answer because the antimicrobial pharmacist was full-time before she went on maternity leave and then she is going to come back part-time. It would be difficult to pick a number'* (AMP 8).
Respondents indicated that they would not generally spend 100% of their time on antimicrobial duties because they have other responsibilities within their hospitals such as dispensary duties. *One respondent commented, 'I'm the only antimicrobial pharmacist for this trust but I don't spend 100% of my time on antimicrobials'* (AMP

4). Another respondent commented, *'Also, we are not allowed to recruit anymore, also we are going to working more in the dispensary, we are going to be opened at weekends so what we have been originally funded for is being compromised. A lot of hospitals will find that the antimicrobial pharmacists are doing alot less than what they have been funded*' (AMP 8). This question does not account for hospitals that do not have a WTE antimicrobial pharmacist such as reported by interviewee 8. Also, respondents indicated that they were unable to determine exactly what proportion of their time was spent exclusively on antimicrobial duties.

3.6.4 Response generation/formatting problems

Response formatting problems were reported by respondents in 13/83 questions. The primary cause for response generation/formatting problems as reported by respondents was their inability to map the answer(s) to questions from the response options given. Respondents indicated that their inability to respond to these questions was primarily due to the complexity in sourcing or collecting the data required to answer these questions.

Table 3.24 - Question 1.3 (ASAT v15a)

No.	Question
1.3	**Does the DIPC have antimicrobial stewardship included within their job description?**

In response to Q1.3 *(see table 3.24)* respondents indicated that they would feel uncomfortable asking for the DIPC for their job description because the DIPC is usually a very senior member of staff. One respondent commented,
'I have no idea, the DIPC for this hospital is director of nursing for the hospital and I have never seen her job description and I don't think anyone else has. The DIPC is on the board at most hospitals so most people would not have access to her job description. I don't think that anyone could actually answer that question. I wouldn't feel comfortable asking for her job description and at some hospitals it is the chief exec [pause] *quite high level.'* (AMP 8)
Initially, the ASAT was designed to be completed by the antimicrobial pharmacist only, however if a multidisciplinary approach was adopted which included the trust's DIPC then this could potentially overcome problems such as accessing the DIPC's job description.

Table 3.25 - Question 5.11 and question 5.16 (ASAT v15a)

No.	Question
5.11	**Do all staff who administer AMs receive annual training in safe and optimal use?**
5.16	**What proportion of consultants attend training on safe and effective AM prescribing?**

Again, respondents raised the issue about whether they were best suited to complete the ASAT. In response to Q5.11 and Q5.16 *(see table 3.25)*, respondents indicated that generating a response to these questions would be problematic if the data are collected by the AMP only. The AMPs indicated that they were not aware of the training available for nursing staff. They reported that they would be required to investigate and confirm the training content for this staff group. In response to Q5.11, one AMP commented,

'No, it would be quite difficult to answer because any antimicrobial pharmacist may not be aware of the training competencies of all staff and how often they would have an update for example nurses who administer antimicrobials would have training in IV administration but how often that competency is assessed. I don't know. I would have to speak to one of our nurse educators [pause] *it may be around medicines management but not specifically antimicrobials'* (AMP 6).

In response to Q5.16, one respondent commented, *'We don't routinely target them, I don't know if part of their non-medical training they would get that'* (AMP 3) and another respondent commented,

'It would be very difficult to determine the proportion. Non-medical prescribers have to attend so many meetings a year but it would be quite variable to see how many attend each meeting... you could get the numbers but how would you go about working out the proportion?' (AMP 8)

Table 3.26 - Question 5.14 and question 5.15 (ASAT v15a)

No.	Question
5.14	**What proportion of registrars/specialist trainees attend training on safe and effective AM prescribing?**
5.15	**What proportion of consultants attend training on safe and effective AM prescribing?**

In response to Q5.14 and Q5.15 *(see table 3.26)* respondents indicated that newly employed doctors will receive mandatory training on antimicrobial prescribing.

However, there were no formal, mandatory training sessions or planned continuing education for registrars and consultants who are currently employed by their hospitals. One respondent commented,

'There would be proportion that gets it on induction [pause] *I'm thinking* [pause] *if we are talking about newly inducted grades of staff there would be a proportion but I wouldn't know what it is* [pause] *if we are talking about existing staff like SpRs and specialist trainees then the answer would be zero. I was going to say that one of our infectious disease consultants have done a session at the weekly Grand Round* [pause] *again we wouldn't have figures for that* [pause] *but some would have attended. Consultants* [pause] *zero.'* (AMP 7)

Respondents reported that potentially it was possible that there were a proportion of these staff groups who would not have any current and relevant antimicrobial prescribing training since their undergraduate studies.

Domain 7 *(see table 3.27)* of the ASAT examined the processes hospitals used to provide patients, carers and the public about antimicrobials. Respondents reported that highly complex and time consuming methods would be required to collect the data for this section of the ASAT. In response to Q.7.2, respondents commented that generally each patient and/or their legal guardian would be informed that the patient about prescribed antimicrobials and why antimicrobials were prescribed, one respondent commented, *Ok, I would say that should happen for everybody'* (Interview 2).

Table 3.27 - Questions 7.1 to 7.7 (ASAT v15a)

No.	Question
7.1	**Is there a policy for providing information on AMs to patients?**
During inpatient admission	
7.2	**Are patients or their legal guardian usually (>80% of the time) informed that they have been prescribed an AM and the reason why an AM is necessary?**
7.3	**Are patients or their legal guardian usually informed of the risks and side effects associated with AM treatment?**
Discharge prescription	
7.4	**Are patients or their legal guardian usually informed that they have been prescribed an AM to take home and the reasons why an AM is necessary?**
7.5	**Are patients or their legal guardian usually informed of the course length and the importance of finishing the course?**
7.6	**Are patients or their legal guardian usually informed about possible risks and side effects of AMs and what to do if side effects develop at home?**
7.7	**Has there been an explanation on the AM given to the patient?**

Also, respondents indicated that patients who have been previously prescribed antimicrobials would have prior knowledge about antimicrobials, one respondent commented, *'Generally, patients who have been on an antimicrobial previously would know about them* (AMP 6). Another respondent commented,
'*I would hope that when someone prescribes an antimicrobial that if the patient is cognitively able to take in the information* [pause] *that the prescriber would say I would prescribe this because you have a chest infection but trying to get stats on that would be near impossible'* (AMP 2).
Other problems reported that related to this question were respondents used estimation strategies to generate an answer. However, this estimation may not be an accurate reflection of their current practice. One respondent commented, '*Yes, I think so, however, you would be guessing* (Interview 6), another respondent commented,
'I don't think I would be able to answer these questions unless we were to do a survey on what information they were given. It's the answers to these questions because you want a percentage [pause] *I would say that should happen most of the time but I couldn't give you a figure'* (AMP 7). Another issue raised was based on the information given to patients by nursing staff and how would this information be documented, one respondent commented, '*Where would that data recorded? It is documented anywhere? How will we be able to collect data on what the nursing staff do?'* (AMP 6).
In response to Q7.3, respondents indicated that giving advice to patients on the side-effects of antimicrobials rarely occurred in their hospitals. One respondent commented, *'I would say that rarely happens but again capturing stats on that would be difficult'* (AMP 2). Respondents reported that this data would be very difficult to capture when patients are given advice because prescribers would not document or record any counselling given to patients on antimicrobial side-effects. However, respondents indicated that if they personally prescribed antimicrobials, they may be able to able to capture the data because they generally advised patients to read the information leaflet. One respondent commented, '*I don't know how to answer that, I could answer that for patient on the antimicrobial ward round but not for every patient in the hospital*' (AMP 3). Respondents indicated that they could not account for the counselling on antimicrobials given in Accident and Emergency (A&E) because these patients received pre-packs of antimicrobials on discharge for example one

respondent commented, '*We wouldn't be sure of what happens in A&E so I wouldn't say 100%'* (AMP 4)

In response to Q7.4, respondents reaffirmed the issue regarding the counselling patients on antimicrobials given by other staff groups and departments where the antimicrobial pharmacist does not routinely visit such as A&E. The data on day-case and A&E patients were not accessible to them because they are involved in prescribing antimicrobials in these departments. One respondent commented, '*A huge number of patients will come in and out of the hospital and never be seen by a pharmacist for example day case or short stay patients'* (AMP 6).

Respondents indicated that their hospitals could report 100% compliance in response to Q7.5 because information on course length was always printed on the prescription box. One respondent commented, *'Yes it's on the label, the course length is always on the label'* (AMP 8). However, they were unable to comment on whether patients received any counselling on the importance of finishing the course. In response to Q7.6 and Q7.7, most respondents indicated that they would not provide information on risks and side-effects on discharge personally. However, advice may be given prior to discharge by nurses or doctors, but respondents were unsure about whether this occurs at each discharge. One respondent commented, *'I would say that the answer to that question is no. I know that from a personal point of view that I tell patients about specific risks for example clindamycin because senior management tells you that you have to. However, with other drugs if there are particular side-effects then you would need to counsel the patient about them. I would not go through the entire list of drugs and tell them all the side-effects or risks of the drugs because the patients would never take them. I would say that doesn't happen. If the patient asked then you would tell them but I wouldn't say that antimicrobial pharmacists would necessarily volunteer that information. Just because people wouldn't take anything, if you went through all the side-effects and risks of the drugs* [pause] *no one would ever take anything'* (AMP 1).

3.6.5 Other findings

In this section I will discuss other findings that were identified from analysing the verbal reports. These emergent themes were not coded as cognitive difficulties as

such but some of the findings could possibly occur as a result from the cognitive difficulties respondents encountered during the survey interaction process. These findings included question duplication, double-barrelled questions, key concepts or questions, ASAT scoring and weights and general feedback on the ASAT which will be discussed.

3.6.5.1 Question duplication

Respondents reported that they viewed 18/83 questions as duplications. Respondents indicated that they viewed questions as duplications of each other because the questions appeared to be measuring similar concepts. The presence of vague or ambiguous terminology was the primary reason reported by the study participants *(see section 3.6.1.2)*.

Table 3.28 - Questions 3.3 and 3.4 (ASAT v15a)

No.	Question
3.3	**Is there guidance on dosing optimisation for AMs with a narrow therapeutic index?**
3.4	**Is there guidance on TDM for high risk AMs?**

In response to Q 3.3 and Q3.4 *(see table 3.28),* respondents indicated that these questions appear to be measuring the processes required for therapeutic drug monitoring (TDM). One respondent commented, '*Now these two questions are similar...Am I answering the same question?'* (AMP 5). Respondents reported that the standard practice was TDM was performed for patients treated with antimicrobials with a narrow therapeutic index. One respondent commented, '*I'm assuming* [pause] *what's the difference between the narrow therapeutic index and the high risk antimicrobials? It's almost like the same question really* [pause] *to me that's like the same question. I know with dosing optimisation that there is the risk of toxicity but to me that's what TDM is* [pause] *it all falls under the same thing'* (AMP 7).

Table 3.29 - Questions 4.2 and 4.4 (ASAT v15a)

No.	Question
4.2	**Is compliance with AM prescribing Policy audited and fed back in each specialty at least once a year**
4.4	**Is adherence to pertinent treatment guidelines audited and fed back in each specialty at least once a year?**

Q4.2 and Q4.4 *(see table 3.29)* were considered duplicates because respondents reported that these questions measure the adherence to antimicrobial prescribing policy. In response to Q4.4, one respondent commented, *'No, we don't anything around adherence to policy. I suppose that maybe if in Urology, the UTI guidelines are followed, so no apart from the main point prevalence study we don't do anything more, it's like a duplicate of 4.2 isn't it?'* (AMP 3).

Table 3.30 - Questions 5.4, 5.5, 5.8, 5.9, 5.10 and 5.11 (ASAT v15a)

No.	Question
5.4	**Is an annual update in safe and effective AM prescribing mandated for all prescribers?**
5.5	**Is an annual update in safe and effective AM prescribing available for all prescribers?**
5.10	**Do all staff who prescribe AMs receive annual training in safe and optimal use?**
5.8	**Is an annual update in safe and effective AM prescribing mandated for all staff who administer AMs?**
5.9	**Is an annual update in safe and effective AM prescribing available for all staff who administer AMs?**
5.11	**Do all staff who administer AMs receive annual training in safe and optimal use?**

Respondents indicated that Q 5.4, Q 5.5, and Q 5.10 *(see table 3.30)* were measuring the concept of the training given to prescribers on prudent antimicrobial prescribing. Similarly, they indicated that Q 5.8, Q 5.9 and Q5.11 *(see table 3.29)* were measuring the concept of training given to staff who administer antimicrobials on prudent antimicrobial prescribing. The primary cause of respondents viewing these questions as duplicates was due to the respondents' interpretation of the terms *'safe and effective antimicrobial prescribing'* and *'safe and optimal use of antimicrobials'*. Respondents indicated that these phrases have similar meanings which are based in the prudent prescribing of antimicrobials. One respondent commented, *'I don't understand how that differs from safe and effective prescribing. I don't see how it differs. It's similar to the questions above* (AMP 4). These questions were also viewed as identifying whether the competency of these staff groups were assessed as part of the education and training strategy. One respondent commented,

'No, it would be quite difficult to answer because any antimicrobial pharmacist may not be aware of the training competencies of all staff and how often they would have

an update for example nurses who administer antimicrobials would have training in IV administration but how often that competency is assessed. I don't know. I would have to speak to one of our nurse educators. It may be around medicines management but not specifically antimicrobials' (AMP 6).

Table 3.31 - Questions 6.1 and 6.2 (ASAT v15a)

No.	Question
6.1	**Is there a substantive AM pharmacist post in place?**
6.2	**Is there an AM Pharmacist in post or in the process of recruitment?**

Respondents viewed Q6.1 and Q6.2 *(see table 3.31)* as measuring whether the trust currently has an antimicrobial pharmacist in post. The intent of Q6.1 was to measure whether funding has been allocated for an antimicrobial pharmacist post and Q6.2 was measuring if there was an antimicrobial pharmacist currently in post. One respondent commented, *'What does substantive mean? Probably means someone dedicated to that role* [pause] *is it relevant?'* (AMP 1). Another respondent commented, *'What's the difference between question 6.1 and question 6.2? Isn't that a duplication?'* (AMP 3).

Table 3.32 - Questions 6.7 and 6.8 (ASAT v15a)

No.	Question
6.7	**Does the lead AMP have written objectives within the last year?**
6.8	**Has the AMP have a PDP within the last year?**

Respondents indicated that they were unsure whether there was a difference between Q6.7 and Q6.8 *(see table 3.32)*. Personal Development Plan (PDP) and written objectives were seen as measuring similar concepts because the PDP was generally linked to their written objectives. Respondents suggested that the PDP and the written objectives should be linked into their trusts' antimicrobial strategy and/or infection control strategy. One respondent commented,
'Is that in relation to our job or in relation to what we should be doing? [pause]*Yes, because we all have objectives i.e. I know what I need to do put it that way. I think it*

should be more [pause] *'Does the antimicrobial pharmacist have written objectives that are linked in with the antimicrobial plan or the infection control plan for the year? Because that's the plan we work to if you know what I mean or whether it is asking about us in our role and getting better at something, I guess that would be our PDP* [pause]*So Q6.7 needs clarification, because you could have objectives which are not necessarily linked to the antimicrobial or infection control plan'* (AMP 2).

Table 3.33 - Questions 7.1 and 7.7 (ASAT v15a)

No.	Question
7.1	**Is there a policy for providing information on AMs to patients?**
7.7	**Has there been an explanation on the AM given to the patient?**

Q7.1 and Q7.7 were viewed as measuring the concept of information given to patients about antimicrobials (AMP 2 and AMP 4). Respondents were unable to make the distinction between these two questions because Q7.1 *(see table 3.33)* measured whether the trust had a policy for the information given to patients on antimicrobials and Q7.7 (see above) measured whether an explanation was given to the patient about the antimicrobials they were prescribed. One respondent commented,

'I would say that Q7.7 is the same as Q7.1. I would answer this question the same way but again trying to get stats on it would be very difficult. These would be very difficult to capture. Again, you would have to ask if that policy would be specific to antimicrobials or just a general policy. Within the medication policy in the trust, I imagine that people would have it their general medication policy but not specific to antimicrobials because explaining why someone is having something and what it's for. Maybe it's less relevant for antimicrobials because they are going to take it for 2-3 days whereas some of the other drugs could go on for life. So if you ask about a policy as being part of the medicines policy [pause] *that's ok. Ask other people but I would say that would be very difficult to capture'* (AMP 2).

Other respondents viewed Q7.7 as a duplication of the preceding questions in section 7. One respondent commented, '*what does this question mean? I don't see why it is different to the ones above, what does it relate to* [pause] *for example side*

effects, risks [pause] *what is it for? This question is carried from the ones above'* (AMP 4).

Table 3.34 - Questions 7.3 and 7.6 (ASAT v15a)

No.	Question
7.3	**Are patients or their legal guardian usually informed of the risks and side effects associated with AM treatment?**
7.6	**Are patients or their legal guardian usually informed about possible risks and side effects of AMs and what to do if side effects develop at home?**

In response to Q 7.3 and Q7.6 *(see table 3.34)* respondents indicated that if information was given on the side-effects and risks of antimicrobial therapy on admission that there was no need to repeat the process on discharge. One respondent commented, *'So it's kind of like the inpatient question, if you did it admission you shouldn't have to do it on discharge as well. So it's a duplication of questions Q7.3 and Q7.6'* (AMP 3). There was no indication within the ASAT on whether the question was referring to oral or written information. Respondents were unable to comprehend that the ASAT was asking about similar processes that occur during admission (Q 7.2 to Q7.4) and discharge (Q7.5 to Q7.7), therefore the questions in section 7 were viewed as duplicates.

3.6.5.2 Double-barreled questions

3/83 questions were viewed as measuring more than one process by respondents. Double barrelled questions measure more than one concept or process. These questions possess more than one question embedded within them. Respondents indicated that they had difficulty in responding to these questions due to the presence of multiple concepts being measured.

Table 3.35 - Question 2.8 (ASAT v15a)

No.	Question
2.8	**How frequently are 2.1, 2.2, 2.6 and 2.7 reviewed?**

In response to Q2.8 *(see table 3.35)*, respondents indicated that the review of antimicrobial policies, antimicrobial formularies, antimicrobial treatment guidelines and surgical prophylaxis guidelines occur at different frequencies within their

hospitals. It was not possible to review each document at the same frequency because these documents may be modified due to publication of new evidence. One respondent commented, *'But obviously if something important came out, like if a major piece of guidance comes out for example when the big C.diff paper came out everyone reviewed their guidelines and it takes forever to review them'* (AMP 2). Other factors that will impact on the frequency that these documents were reviewed were identified by respondents. These factors included local sensitivity patterns, types of wards such as critical care wards and also the age group of patients such as adults and paediatric patients. One respondent commented,

'Well [pause] *ideally yearly, this would be difficult for me to answer because I aim to do all of them yearly but we have a treatment guideline for adults, prophylaxis guideline for adults, treatment and surgical prophylaxis guideline for paeds, so I would aim to do all four of them each year but it is really a lot of work. I think that other people wouldn't necessary review their treatment guidelines every year or even more frequently but the prophylaxis guideline may stay the same, maybe they should be separated out and include other sections as well. Maybe as well policy review should take into place new evidence and (your certain sections) local sensitivities, might be more important in certain specific areas so critical care areas, ITU, and Haematology. This could be an indicator of good practice. Not mentioned in tool'* (AMP 1)

Consequently, respondents suggested that this question should be split into four different questions where each question would measure the frequency of review for each type of document.

Table 3.36 - Question 2.13 (ASAT v15a)

No.	Question
2.13	**Does the Microbiology Laboratory use selective reporting of results in line with formulary choices?**

Respondents indicated that they viewed Q2.13 *(see table 3.36)* as measuring the processes used by clinical microbiology to report antimicrobial sensitivity results. They stated that their microbiology laboratories may use selective reporting of results but they may not necessarily be in line with choices or options available in the formulary. Respondents suggested this question should be divided into two questions in order to increase question sensitivity. One respondent commented,

'This drives me mad because they don't always report on antimicrobials that are on our formulary therefore reporting on others that aren't [pause] *this can confuse prescribers for example, they report on erythromycin sensitivity which we don't use erythromycin, we use clamycin so I think the answer to that is 'yes' they do it but not in line with the formulary so whether it should be two separate questions for example* [pause] *'Does it use selective reporting?' and 'Is it in line with formulary choices?' Yes, they do selective reporting so they don't give out all the antimicrobials i.e. they keep some results back but it is not always in line with the formulary. But I think that comes from a lab point of view, because they do the little test 'thingies' and every time they bring in a new disc of a new antimicrobial, it takes so long to bed into their systems in the lab , and their IT systems and their machines. So maybe it is not as easy as hoped for example maybe they just stick a disc on and it all will be fine. It is not that simple to change what they are doing. Therefore I would recommend that you split that question'* (AMP 2).

Table 3.37 - Question 4.11 (ASAT v15a)

No.	Question
4.11	**Are there action plans agreed and recorded and shared with the AM committee?**

Q4.11 *(see table 3.37)* aims to measure the processes which trusts utilised to ensure that any action plans generated from antimicrobial-related audits were feedback to the antimicrobial stewardship committee. In response to Q4.11, respondents indicated that this question was generally easy to understand however it appeared to be measuring multiple processes which included agreeing, recording and sharing actions plans with the antimicrobial stewardship committee. Respondents suggested that in order to improve question sensitivity this could be divided into two questions. One respondent commented, *'there are always action plans for audit* [pause] *but audits are always conducted centrally and then there are fed out. Maybe that needs clarification because the antimicrobial committee that overall monitors for that so they would need to ensure that the actions have been carried out. I think that's what it is getting at so* [pause] *Are there action plans agreed for each audit conducted? Does that antimicrobial committee monitor completion of actions relating to antimicrobial audits?* [pause] *therefore questions should be split'* (AMP 2)

3.6.5.3 Irrelevant key concepts or questions

Respondents reported that they viewed 6/83 as containing irrelevant or redundant concepts. Respondents proposed that some questions were either irrelevant or contained irrelevant concepts regarding the current practice of AMS within their hospitals. The primary reason for this was that the ASAT was designed prior to these practices become standard practice within NHS Trusts.

Table 3.38 - Question 4.11 (ASAT v15a)

No.	Question
2.11	**Is an easily accessible printed summary available to all wards and prescribers (e.g. pocket guide)?**

In response to Q2.11 *(see table 3.38)*, each trust indicated that their antimicrobial guidelines were located on their trust's intranet. It was not common practice to provide each prescriber with printed summaries of the antimicrobial guidelines. Respondents indicated that they thought that printed copies were beneficial but highlighted that the main problem with this format was version control. One respondent commented, *'Having pocket guides is beneficial I think, but then there would be problems with version control*' (AMP 2). The Drug and Therapeutics Committee would be consulted each time these documents required updating so therefore most hospitals have adapted electronic versions of the guidelines which were accessible from any ward. One respondent commented, *'they would need prior approval from Drug and Therapeutics Committee and when they are updated again, another round of approval will have to be done. That is one of the reasons we went for electronic because of the ease of updating things. Paper stuff gets so out of date so quickly, we do have laminated cards with a list of common infections but that's where we are up to'* (AMP 4). Some respondents indicated that antimicrobial prescribers within their hospitals preferred to download guidelines to their personal digital assistants (PDAs). One respondent commented, '*There have been surveys done on what our junior doctors prefer in terms of how they like their antimicrobial guidance they seem to be happy about what is available on our intranet. Some doctors have said that written copies they would lose anyway so they would prefer an application that they can download onto their PDAs. If you*

weight that quite heavily I am not sure that's fair. You will get some people who want written guidance but it's around accessibility and ease of use. Some e-guidance is not easy to navigate' (AMP 6). Each respondent indicated that at induction every antimicrobial prescriber were signposted to the location of antimicrobial guidelines on the intranet.

Table 3.39- Question 4.10 (ASAT v15a)

No.	Question
4.10	**Is attendance at audit feedback meetings recorded?**

In response to Q4.10 *(see table 3.39)*, respondents indicated that they were unsure of the relevance of this question because they reported that they did not believe that recording attendance at audit feedback meetings will improve ASPs within their trusts. One respondent commented, *'It is, but I'm not sure if that makes any difference to anything whatsoever*' (AMP 1). Respondents reported that they were unsure of the role of audit feedback meetings in ASPs. They queried whether the roles were to update attendees on audit results and findings or to discuss action plans generated from antimicrobial-related audits with relevant staff groups. One respondent commented, *'I do not see the relevance of this question* [pause] *Is it to update attendees on guidelines and audit findings? Is it just to ensure that every appropriate staff group is present? I am not sure of the relevance of the question'* (AMP 4). One respondent indicated that they currently did not have dedicated antimicrobial audit meetings within their hospitals.

Table 3.40 - Question 5.2 to 5.3 (ASAT v15a)

No.	Question
5.2	**Do all AM prescribers receive printed information about AM prescribing, formulary and guidelines at induction?**
5.3	**Do all pharmacists receive printed information about AM prescribing, formulary and guidelines at induction?**

Q5.2 and Q5.3 *(see table 3.40)* measured whether hospitals provide antimicrobial prescribers and pharmacists with printed information about antimicrobial prescribing, formularies and guidelines at induction. Similar to the response to Q2.11, respondents indicated that that they were unsure about the relevance of these

questions because all guidelines and formularies are available electronically. One respondent commented, '*they will receive an induction booklet which will tell them where to access all the information because all the information is electronic we don't print it out and give it to them. We definitely direct them to where it is kept on the internet. Again, I do not know how many people if you have electronic guidelines will print them out and distribute them* [pause] *the question will need to be updated*' (AMP 4).

Table 3.41 - Question 5.12 and question 5.17 (ASAT v15a)

No.	Question
5.12	**Do all staff who dispense AMs receive annual training in safe and optimal use?**
5.17	**What proportion of staff who administer AMs attend training on safe and effective AM prescribing?**

In response to Q5.12 and Q5.17 *(see table 3.41)*, respondents indicated that they were unconvinced that staff who dispense or administer antimicrobials required training in safe and effective antimicrobial prescribing. In response to Q5.12, one respondent commented, *'Dispensing has to do with the labelling of products so I wouldn't do anything for them really...'* (AMP 4) and another respondent commented, *'Training sounds like it something you would need to be signed off for to show that you were competent, I'm not sure that they would need that. You would train a nurse on how to administer, but the pharmacy technicians you would just say things like be careful how much you give out etc.'* (AMP 3). In response to Q5.17, one interviewee commented, *'Again, I am not sure of the relevance of staff who administer antimicrobials, how much would they need to know about safe and effective prescribing...there is nothing formal for them. The question needs rewording to* [pause] *what proportion of staff who administer antimicrobials attend training on safe and effective administration?* [pause] *It is not in their remit.'* (AMP 4) Potentially, these staff groups could be utilised as a final check to ensure that antimicrobials have been prescribed appropriately.

3.6.5.4 ASAT scoring and weights

Generally, respondents indicated that they agreed with the weightings assigned to the questions within the ASAT and understood the rationale behind the scores. However, there were 13/83 questions where respondents disagreed the scores

assigned. Respondents queried the relevance of the weightings and the implications of these scores on the total overall score generated from an ASAT evaluation.

Table 3.42 - Question 1.5 (ASAT v15a)

No.	Question
1.5	**How often does it meet?**

In response to question 1.5 *(see table 3.42)*, respondents indicated that the ASAT assigned a higher score to a more active committee. Respondents indicated that they believed that the developers of the ASAT were assuming that a committee that met more frequently was more effective within hospitals. Also they indicated that this question did not have sufficient sensitivity to assess the impact of the antimicrobial committees. One respondent commented,

'Quarterly, yeah[pause] *in terms of the scoring, I don't know whether* [pause] *maybe it's quite important, I think that the ASAT is giving higher scores to a more active committee* [pause] *so actually is the scoring valid? Because a trust could be quite rubbish but they could have a committee that meets every week, but that doesn't mean that they are doing anything'* (AMP 1).

Table 3.43- Question 2.7 (ASAT v15a)

No.	Question
2.7	**Are peer-reviewed, evidence-based, surgical prophylaxis guidelines available for the common procedures?**

In response to Q2.7 *(see table 3.43)*, respondents indicated that some specialist trusts would not have guidelines for each common procedure as stipulated by the SACAR template because they would only have guidelines for the procedures conducted in their trusts. They suggested that points should be allocated for the percentage of procedures that their guidelines cover within their hospitals. One respondent commented,

'Again, it would just depend if it's for the majority of procedures... In our hospital the common ones are orthopaedics but we don't have them for everything. I suppose if you have 1 point for 50% of things... points should be allocated to percentage of procedures covered' (AMP 3).

Table 3.44 - Question 2.8 (ASAT v15a)

No.	Question
2.8	**How frequently are 2.1, 2.2, 2.6 and 2.7 reviewed?**

Respondents indicated that was difficult to answer Q2.8 *(see table 3.44)* mainly due to the different review frequencies for policies, guidelines and formularies. Some respondents indicated that they assign the highest score to their organisation. One respondent commented, *'Well for anything new I have been saying every year but for existing guidelines I would say every two years so it is a bit of both really. I see that you have given a score of 2 for yearly, 1 for every two year… so I would give myself the most generous score'* (AMP 7).

Table 3.45 - Question 2.11 and question 5.2 (ASAT v15a)

No.	Question
2.11	**Is an easily accessible printed summary available to all wards and prescribers (e.g. pocket guide)?**
5.2	**Do all AM prescribers receive printed information about AM prescribing, formulary and guidelines at induction?**

In response to Q2.11 and Q5.2 *(see table 3.45)*, respondents indicated that they did not agree with the weighting for this question because their trusts do not produce paper copies of guidelines as standard practice. They agreed that having pocket guides is good practice however the main problem with this format is version control. One respondent commented, *'Having pocket guides is beneficial I think, but then there would be problems with version control* [pause] *but 'is it available?' the answer would be no. I think you weighted highly, and I think that is a good thing, the junior doctors do like it. The high weighting is good. You are trying to balance the version control with accessibility*' (AMP 2).

Also, they suggested that this question should be updated to reflect the current practice of having guidelines available electronically. One respondent commented, *'No* [pause] *3 points for yes? We do have a poster on A&E on the back of Saving Lives. But I don't know how you could answer yes to that if you have paper copies flying around the hospital. We have everything electronic here for example notes etc. so why would we have paper copies of the policy? I could answer it but I don't know if I agree with missing out on points.* (AMP 3)

Table 3.46 - Question 2.14 (ASAT v15a)

No.	Question
2.14	**Does the AM policy stipulate that indication should be recorded before AMs are prescribed?**

Respondents indicated that they were not in agreement with the scoring for the response options for Q2.14 *(see table 3.46)*, that is, 1 for notes, 2 for prescription and 3 for both (notes and prescriptions). The primary reasons highlighted by respondents were that they were not in agreement with the weighting of this question in comparison with other questions because this question (Q2.14) only measured the content of the policy but not compliance. One respondent commented, '*Yes, however, I think comes onto the audit bit, but the important thing is how often it is acted on, so I don't think that the scoring is correct. For prescription that scores 2, which is quite high when compared to other things that you have to do to get the score, and yet it is only about putting a sentence in a policy. The important thing is what you do with it*' (AMP 1).

Some respondents indicated that their policy states that the indication should be recorded but not where it should be recorded. They agreed that it should be recorded in both the notes and on the prescription. One respondent commented, '*Yes but that doesn't say where, the policy stipulates that it should be recorded but it does not say where it should be recorded on the drug chart or the notes. It should be recorded in both'* (AMP 2). They suggested that the score for *'notes'* should be higher or equal to the score for *'prescription'* because the notes were the complete patient record and prescribers should be encouraged to clearly state the indication in the patient notes. One respondent commented,

'*I don't know if it should be the other way around really because the notes are the complete record, prescription charts sometimes get lost, I don't know if prescription should have a higher weighting. In terms of my role, the prescription is more important because that is what I look at but in reality the notes are the complete record so if it doesn't say why you have prescribed it in the notes… on the prescription you can write a limited amount on information and in the notes you should have a full explanation of why an antimicrobial has been prescribed and how long for* [pause] *so the scoring should be the other way around or equal.* (AMP 8)

Table 3.47 - Question 3.6 (ASAT v15a)

No.	Question
3.6	**Are incident reports of AM usage fed back to the AM committee or other groups?**

Respondents indicated that the scoring for Q3.6 *(see table 3.47)* should be increased because it should be compulsory that antimicrobial-related incident reports should be fed back to the antimicrobial stewardship committee. This can potentially positively impact the AMS agenda within NHS organisations because these incidents will be reported and discussed among members of the committee and action plans can be generated. These action plans may trigger audit projects and which could feed into the antimicrobial education strategy for the trusts. One AMP commented,

'Not always [pause] *The 'other group' thing needs clarifying because the other groups may not mean the people on the antimicrobial committee may know about it, and so here there would be reported to each division, clinical governance meetings and so for instance we have a women's hospital which houses Obs and Gynae surgery, which may have different incidences or errors that happened there but because those never got pulled you never pick them up that it is bigger problem than it is. So actually this is quite important and should be reflected in the weighting of the scores. A lot of weighting around policy but it's what you do with it e.g. NHSLA scores that would be a good kind of good template to weight the questions'* (AMP 1).

Table 3.48 - Question 4.2 (ASAT v15a)

No.	Question
4.2	**Is compliance with AM prescribing Policy audited and fed back in each specialty at least once a year?**

In response to Q4.2 *(see table 3.48)*, respondents reported that hospitals a higher score should be given to hospitals that audit their compliance to the antimicrobial policy more frequently than annually. They suggested that an active antimicrobial audit programme will be beneficial to establishing and promoting prudent antimicrobial prescribing within their trusts. One respondent commented,
'Yes, maybe you could have more weighting for trusts that do that more often. I know it depends on how much time the antimicrobial pharmacist has and how much support they get. I know that some trusts do it every couple of months and we do it

here 4 times a year. Some trusts do it less than us so maybe there could be more weighting for how often they do that' (AMP 2).

Several concerns were raised by respondents about the weighting for the questions in section 5 *(see section 3.6.1.2)* as opposed to other questions within ASAT v15a. For example, respondents indicated that they did not agree with the scoring for Q5.9 because they did not believe that staff that administer antimicrobials would not need an update on safe and effective prescribing so therefore it is not common practice within their trusts to train this staff group. One respondent commented, *'There are a lot of points for this. If this is for the nursing staff, it would be a nightmare really. Prescribers should be updated so therefore a higher weighted score would be applicable. Do they need an update on safe and effective prescribing? You would lose out on points if those who administer antimicrobials are not updated for example nurses'* (AMP 3).

Respondents suggested that a higher weighting should be applied to Q5.19 because they reported that they agreed that all antimicrobial prescribers should be competency assessed. However, in most trusts the only staff group that is competency-assessed are non-medical prescribers. One respondent indicated, *'Just for the non-medical prescribers, we are thinking of having a web-based competency questions for doctors...in conjunction with the medical schools in the region'* (AMP 4). Also, they reported that medical prescribers were not routinely competency assessed. One respondent commented,
'that question is quite difficult because you would only get one point for yes. There are consultants who have worked here for years and they are never competency assessed. You may end up with misleading answers or scoring' (AMP 6).
Respondents indicated that they did not believe that section 5 was adequately measuring the education and training processes within their organisations. They reported that they viewed these questions as vague and imprecise because they were not adequately tailored to local trust priorities. One respondent commented,
'We do a lot of training but it's not necessarily safe and effective prescribing for example we might do training on C.diff with various staff groups and we have done specific training sessions on areas where we have problems. The microbiologists have looked at respiratory infections because we had problems with prescribing for

pneumonia for UTIs so they have done specific training for that area. It's not obvious from section 5, that we have done things like that, we are answering 'no' to most of these but we do a lot of education and training for prescribers, nurses and pharmacists and that is not reflected in the questions that you have asked there. You are just asking a generic question on safe and effective but we have tailored our training to the locally identified needs of the trust. We would look bad on that even though we have done a lot of work on it. We focus on the issues that are causing us problems. When I was completing this section I was thinking of an infection e-learning package... something quite formal. We have mandatory training packages for infection control, fire safety and lifting and handling. We do not have one of those for antimicrobials as we conduct the training differently. That's how most people would view mandatory training. Are you doing regular training? It sounds like if it's the same training each year... we would have to do something different each year. (AMP 8)

Table 3.49 - Question 6.1 (ASAT v15a)

No.	Question
6.1	**Is there a substantive AM pharmacist post in place?**

Respondents viewed their role as crucial to the success of AMS in their hospitals. In response to Q6.1 *(see table 3.49)*, respondents indicated that a higher score should be allocated to this question. One respondent commented, *'Yes, easy question but it should be worth more. 'You need an antimicrobial pharmacist, it's not just worth than (Y=1), we're worth more than that!'* (AMP 2).

Table 3.50 - Question 6.4 (ASAT v15a)

No.	Question
6.4	**Does the lead AMP have >3 years experience in this specialist role?**

In response to Q6.4 *(see table 3.50)*, there were conflicting views on the scoring of this question. Respondents indicated that a more experienced AMP should be scored higher, one respondent commented, *'Maybe you should get more if you have more experience'* (AMP 2). Conversely, other respondents did not agree that trusts with AMPs with greater experience should be allocated more points but agreed that points should be allocated if there is an antimicrobial pharmacist in post. One

respondent commented, *'I could answer that, I don't really know if they have experience means that it deserves points. If someone is on the role then that deserves points'* (AMP 3).

Table 3.51 - Question 6.6 (ASAT v15a)

No.	Question
6.6	**Does the lead AMP have specialist training in infection management/antimicrobial use?**

In response to Q6.6 *(see table 3.51)*, respondents indicated that a higher score should be allocated to antimicrobial pharmacists with specialist training in infection management. They suggested that this question should be weighted higher that Q6.5, which examined if the antimicrobial pharmacist had a postgraduate qualification in infection management. One respondent commented, *'Again if they have specialist training in infection management, it should be worth more. We are trying to get the Royal Imperial College to come and do some teaching for us but I don't think that they are going to come'* (AMP 2).

3.6.6 Other considerations

During the cognitive interviews, respondents raised other issues with respect to their local organisational practices. These issues were not directly related to cognitive difficulties but respondents indicated that they should be taken into consideration for further ASAT iterations.

Table 3.52 - Question 2.19 (ASAT v15a)

No.	Question
2.19	**Do AM guidelines provide guidance on typical duration of treatment for each indication?**

In response to Q2.19 *(see table 3.52)*, some respondents indicated that the clinical microbiologists within their hospitals have different opinions on the most appropriate duration for antimicrobial therapy. One respondent commented, *'For some, it's difficult to answer that because we have different micro opinions on duration. I think that once we were thinking of having a table of standards of duration. I think for most things duration is there but not for most things'* (AMP 6).

Table 3.53- Question 2.20 (ASAT v15a)

No.	Question
2.20	**Do AM guidelines provide guidance on choice, dose, route, IV switch for each indication as appropriate?**

The dose of antimicrobial chemotherapy given to paediatric patients was weight-dependent. Antimicrobial prescribers in paediatric trusts were required to consult the British National Formulary for Children (BNFc) for guidance on dosing for these patients. Therefore, in response to Q2.20 *(see table 3.53)*, one respondent commented,

'Choice, yes, dose, no, the reason why we do not stipulate dose is because we are a paediatric trust. The dose is different…it depends on the age etc. We want people to refer to the BNFc for everything instead…the doses change from edition to edition so I don't think that it practical to include doses in our guidelines…so choice yes, dose no, route yes, IV switch no because we have an IV to Oral switch guideline which was done after most of our guidelines' (AMP 7). Antimicrobial pharmacists from paediatric trusts will not be able to answer *'yes'* to this question because it was not standard practice to include dosing recommendations in their guidelines.

Table 3.54- Question 4.3 (ASAT v15a)

No.	Question
4.3	**Is compliance with AM Restriction System audited and fed back in each specialty at least once a year?**

Respondents indicated that it would be difficult to answer Q4.3 *(see table 3.54)* because their trusts did not have a stand-alone, dedicated system for restricting antimicrobials. Respondents indicated that they may be unable to audit the use of restricted antimicrobials because accessing this information was very complicated and time consuming. One respondent commented,

'It would be difficult to answer that one really because we do not have a specific report for restricted antimicrobials but as part of your point prevalence audit if someone was on restricted antimicrobials, you would check whether it was valid for that indication or micro approval' (AMP 6).

Table 3.55 - Question 4.5 (ASAT v15a)

No.	Question
4.5	**Is adherence to pertinent surgical guidelines audited and fed back in each specialty at least once a year?**

In most hospitals, surgical prophylaxis was conducted by anaesthetists who generally did not record any data regarding the dose within the patient notes. In response to Q4.5 *(see table 3.55)*, some respondents indicated that a trust-wide point prevalence audit may be unable to identify antimicrobials used for surgical prophylaxis. One respondent commented, *'More difficult because surgical prophylaxis would be given by the anaesthetists in theatre and not recorded on the prescription chart so it won't be picked up on the point prevalence audits. We do have guidance.*[pause] *but is it audited* [pause] *we don't know'* (AMP 6).

Table 3.56 - Question 4.8 (ASAT v15a)

No.	Question
4.8	**Is antimicrobial consumption monitored e.g. DDDs per activity?**

In response to Q4.8 *(see table 3.56)* one respondent indicated that it was not possible to measure defined daily doses (DDDs) for paediatric patients. Antimicrobial therapy for paediatrics was dependent on the weight and age of the patient. The respondent indicated that it was difficult to answer any questions related to antimicrobial consumption i.e. Q4.8 and Q4.9. The respondent commented, *'No, because DDDs isn't possible to measure antimicrobial use in paediatrics* [pause] *because the dose for any child would be different depending on age and weight so you couldn't come up with a DDD for a drug. I have spoken to colleagues in paediatric trusts* [pause] *but we couldn't come up with a way to measure DDDs* [pause] *even though it is a good method of measuring DDDs so that you can quantify your usage and compare it with other trusts*. *In paeds we really do not what to do*' (AMP 7).

Table 3.57 - Question 6.6 (ASAT v15a)

No.	Question
6.6	**Does the lead AMP have specialist training in infection management/antimicrobial use?**

Currently, there was no specialist training in infection management in the northwest of England because it was only available in London. They were unable to access the training because they were unable to obtain study leave. In response to Q6.6 *(see table 3.57)*, one respondent commented, *'No we don't have anything in the northwest...you will get different answers in different parts of England'* (AMP 8).

3.7 Discussion

The implications of the findings from Study 1 are discussed in this section of the chapter. An overview of the modifications described in this section and a detailed description is provided in the modification table (ASAT v15a to ASAT v16) *(see Appendix XXIV)*. This table contains each modification made to the ASAT v15a and also provides the rationale for each modification.

3.7.1 Implications on the development of the ASAT

From the results of the cognitive interviews conducted in this study, it was clearly demonstrated that there were problems associated with the content of ASAT v15a. Respondents reported difficulties at word, phrase and question level. These problems provided signals/indications for further revisions. The findings of this study were discussed with the chair of ARHAI who also recommended changes to ASATv15a. These recommendations were based on the findings of this study. The next phase of this study was to address the reported problems by modifying the ASAT 15a to produce ASAT v16. These modifications *(see Appendix XXIV)* are discussed in this section of the chapter and are summarised in table 3.58.

Table 3.58 -The process of development, testing and item reduction for ASAT v15a from ASAT v16[1]

Study type	Method	ASAT version	New	Retained	Modified	Deleted	Total
Qualitative	**Item construction** Consensus expert review and literature review (ARHAI)	**15a**	83	n/a	n/a	n/a	83
Qualitative (Study 1)	**Content validity** Cognitive interviews with antimicrobial pharmacists	**16**	2	25	58	4	85

[1] *'New' represents questions that were developed from newly constructed questions including question merging. 'Retained' represents questions that remain unchanged. 'Modified' represents questions that were altered for example by conducting word insertions and word deletions*

3.7.1.1 Resolution of comprehension problems

Comprehension or interpretation difficulties were the most commonly reported cognitive difficulty reported by respondents. As previously discussed in *section 2.2.10.4.1*, this phase of cognitive processing informs subsequent phases so therefore it is essential that respondents comprehend what each question is asking and also determining what information is necessary to answer each question. Comprehension problems were primarily linked to respondents' inability to encode questions correctly *(see section 3.6.1)*. The resolution of comprehension problems primarily involved the insertion of comprehension cues into ASAT v16. These comprehension cues were the insertion of definition of identified problematic terms or phrases into the glossary of ASAT v16. Removal and substitution of problematic terms or phrases were also conducted to improve the comprehension of difficult terms or phrases *(see Appendix XXIV)*.

The resolution of comprehension-lexical problems was primarily conducted by the inclusion of definitions into the glossary of ASAT v16 *(see Appendix XXIV)*. The phrases which have been included in the glossary of ASAT v16 were *'antimicrobial stewardship', 'antimicrobial stewardship programmes', 'antimicrobial stewardship committee', 'antimicrobial strategy', 'antimicrobial policy', 'antimicrobial guidelines', 'antimicrobial formulary', 'system for restricting access', 'system for reporting unauthorised prescribing', 'system for entry of new antimicrobials', 'common infections', 'antimicrobial ward rounds', 'education and training strategy',* and *'antimicrobial audit strategy'.* These definitions were sourced from the SACAR Antimicrobial Framework published and also the Antimicrobial Prescribing Policy and Practice in Scotland: Recommendations for Good Antimicrobial Practice in Acute Hospitals .[15;19]

The resolution of comprehension-inclusion/exclusion problems was primarily conducted by removal of vague or ambiguous terminology or phraseology *(see Appendix XXIV)*. These terms or phrases were substituted by terms which were unambiguous *(see table 3.59).*

Table 3.59 - Substituted terms or phrases in ASAT v15a

Question	Original term or phrase	Modified term or phrase
Q1.1	antimicrobial use	antimicrobial stewardship
Q1.5 to Q1.7	it	antimicrobial committee or equivalent
Q3.6	antimicrobial prescribing policy	antimicrobial policy
Q4.4 to Q4.7	adherence	compliance
Q5.3 to Q5.9 and Q5.13 to Q5.18	safe and effective	optimal
Q7.2 to Q7.7	do	How many

Other modifications were made to problematic questions such as question re-wording by the inclusion of words or phrases to clarify the meaning of questions for example Q2.1 '*Is there an antimicrobial policy (overall principles for use) or section in another trust policy?'* was reworded and changed to *'Does your trust have an antimicrobial policy which clearly states the overall principles of antimicrobial use?'.* Q7.2 was the only reported comprehension -computational problem and this was resolved by the removal of *'(>80% of the time)'* from the question.

3.7.1.2 Resolution of information retrieval problems

The triggers for the information retrieval problems reported by respondents were based in the respondents' lack of knowledge about the content of published guidance (Saving Lives) and also their hospitals' practice. In order to resolve the problem with referencing Saving Lives, Q2.16 was reworded therefore Q2.16 *'Does the antimicrobial policy stipulate that prescriptions be reviewed in line with 'Saving Lives'?'* was reworded to *'Does the Antimicrobial Policy* stipulate how often prescriptions should be reviewed?'.* There were instances where respondents were unaware of their hospital practice in terms of the content of education and training packages for non-pharmacy staff that is, Q5.13, Q5.15 and Q5.16. It was felt that these questions should remain in the ASAT after discussions with the ASAT developers. Q5.11 was deleted from ASATv15a due to question duplication *(see section 3.10.1)*. Q1.3 and Q7.1 remained unchanged and the modifications to Q7.2 have been discussed *(see section 3.11.1.1)*.

3.7.1.3 Resolution of judgment/decision problems

Temporal *(see section 3.8.1)* and computational problems *(see section 3.8.2)* were the two types of judgment/decision problems reported by respondents. The main

trigger for the temporal problems was the absence of a specified time period to which the ASAT referred. In order to resolve temporal problems for example Q1.1, a time period was provided in the instructions of ASAT v16. Q6.4 raised the issue the experience of the antimicrobial pharmacist in infection management. Respondents queried whether Q6.4 referred to only experience within their current hospital or did it refer to their total infection management experience. After discussions with the ASAT developers, it was decided that the AMP's total infection management experience should be used to answer this question. Q5.13 and Q5.14 were difficult to answer because respondents were unsure whether these questions were referring to training in safe and effective antimicrobial prescribing at induction or as part of a continuing education programme. These questions were split as follows:

Q.5.13 What proportion of Foundation Year doctors attend training on safe and effective prescribing?

What proportion of Foundation Year doctors attend training on optimal antimicrobial prescribing?

a. *at induction*
b. *continuing education*

Q5.14 What proportion of registrars or specialist trainees attend training on safe and effective prescribing?

What proportion of registrars or specialist trainees attend training on optimal antimicrobial prescribing?

a. *at induction*
b. *continuing education*

Q5.15 to Q5.18 were split in a similar manner because they examined the attendance of other staff groups such as non-medical prescribers at optimal prescribing sessions.

Computational problems were resolved by specifying the denominator which was required to answer Q6.3, that is, the denominator referred to all pharmacy staff involved in antimicrobial duties.

3.7.1.4 Resolution of response formatting/generation problems

The response formatting problems *(see section 3.8)* were triggered by respondents' inability to map their responses to the response options given. This type of difficulty was mainly reported in response to the questions in Domain 7. After discussions with the ASAT developers it was felt that no other modifications should be made to these questions or their response categories. Additionally, respondents indicated that they would counsel patients who have been prescribed antimicrobials as part of the professional practice in order to improve medication adherence *(see Appendix XXIV)*. They felt that, although these were good questions to ask, they would be difficult to measure by the people working in hospitals.

3.7.1.5 Resolution of other (non-cognitive) reported problems

In this section, non-cognitive problems will be discussed. These problems may have resulted from cognitive difficulties but were primarily due to the question construction in ASAT v15a. These types of problems were exemplified by question duplications, double-barrelled and also irrelevant key concepts or questions. Also, there was commentary on the ASAT scores and weightings applied to the responses in ASAT v15a.

3.7.1.5.1 Resolution of question duplications

There were a number of questions interpreted by respondents as duplicates *(see section 3.10.1)*. In other words, they viewed these questions measuring identical processes of ASPs. One of the main triggers for questions being interpreted as duplications was the lack of definitions for problematic terms. The resolution of question duplication in ASAT v15a was conducted by merging questions, rewording questions, including definitions in the glossary of ASAT v16 and also the removal of questions from ASAT v15a.

Q3.3 and Q3.4 were merged into a single question because both questions were interpreted as measuring whether trusts had guidance on therapeutic drug monitoring. Also, Q6.7 and Q6.8 were merged because there were viewed as measuring whether AMPs had a personal development plan within the last year. The modifications made to Q4.2 and Q4.4 which included question rewording have been previously discussed. Q6.1 and Q6.2 were also viewed as duplications of each other so therefore the phrases ‘*within your department*’ and ‘*actively*’ were added to

these questions respectively. Therefore, Q6.1 was changed to *'Is there a substantive antimicrobial pharmacist* post in place within your department?'* and Q6.2 was changed to *'Is there an antimicrobial pharmacist* actively in post or in the process of recruitment?'*.

Both Q5.10 and Q5.11 were removed from ASAT v15a because there were viewed as measuring whether staff who prescribe antimicrobials and staff who administer antimicrobials received annual training on safe and effective use of these drugs. Q5.4 and Q5.5 and also Q5.8 and Q5.9 were viewed as measuring these processes. Also, Q.7.7 was removed from ASAT v15a because it was viewed as measuring the information given to patients about the antimicrobials they have been prescribed. This was viewed as being measured by Q7.2 to Q7.6.

3.7.1.5.2 Resolution of double-barreled questions

Double-barrelled questions typically measure more than one concept and therefore reduce question sensitivity of questionnaires. There were three questions (Q2.8, Q2.13, Q4.11) reported as double-barrelled questions in ASAT v15a. These questions were split into two or more questions in order to improve question sensitivity *(see Appendix XXIV)*. For example, Q2.8 which states *'How frequently are 2.1, 2.2, 2.6 and 2.7 reviewed?'* was split into three questions as follows:

- How frequently is the antimicrobial policy reviewed?
- How frequently are the antimicrobial guidelines reviewed? This question covers both treatment and surgical prophylaxis guidelines as respondents indicated that they may review these guidelines at the same frequency.
- How often is the antimicrobial formulary reviewed?

Q2.13 and Q4.11 were both split into two questions *(see Appendix XXV)*.

3.7.1.5.3 Resolution of irrelevant key concepts or questions

There were six questions that were reported to contain irrelevant key concepts or viewed as irrelevant questions in ASAT v15a. These questions were Q2.11, Q4.10, Q5.2, Q5.3, Q5.12 and Q5.17. Q2.11 asked whether there were easily accessible printed summary of guidelines available to all wars and prescribers. However, respondents indicated that these guidelines were electronically available on their trusts' intranet so therefore they did not used paper-based copies. The phrase *'or*

electronic' was inserted in Q2.11 in order to resolve this problem. Q5.2 and Q5.3 examined whether prescribers and pharmacists were given printed information on antimicrobial prescribing, formulary and guidelines at induction. The word *'printed'* was removed from these questions and also *'antimicrobial prescribing'* was also removed because respondents indicated that information on antimicrobial prescribing would be provided on the job but necessary at induction. No modifications were made to Q4.10. As previously discussed, Q5.12 was removed from ASAT v15a. The modifications made to Q5.17 were discussed in *section 3.11.1.1.*

3.7.1.6 Resolution of issues regarding ASAT weights and scoring

ASPs are complex interventions with numerous components (internal and external), which could make analysing their effectiveness in changing prescribing practice difficult to measure. The ASAT is a composite measure and was designed to evaluate hospital-based ASPs. A composite measure can be defines as *'a combination of separate performance measures which have been combined into a single index or measure and are often used to rank or compare the performance of different practitioners, organisations or systems by providing an overall view of performance'*.[326] It has been recommended that since composite measures are intended to provide a comprehensive performance assessment, they should contain important aspects of performance, even if there are difficult to measure.[326]

One of the main challenges of developing composite measures is determining the appropriate weightings for component measures for an informative evaluation of ASPs. Component measures within the ASAT may be weighted according to the priorities of relevant stakeholders involved in implementing hospital-based ASPs such as antimicrobial pharmacists and clinical microbiologists. Further research is recommended into the investigation of the most appropriate weightings for the ASAT's component measures and domains which are required for an informative evaluation of ASPs. Therefore, based on the results of an ASAT evaluation, hospitals could prioritise their resources into developing effective ASPs.

Respondents indicated that there were 11 questions with inappropriate weightings and scoring. Although, the findings from Rasch modelling *(see section 5.5)* were used to investigate the item hierarchy within each domain of the ASAT, additional

research may be required to determine ASAT question weightings utilising a larger sample size such as all NHS trusts in England.

3.7.1.7 Other interventions

As previously discussed, Davey and his colleagues[10] categorised interventions to promote AMS based on the EPOC classification *(see table 1.8)*. However, there were a number of interventions suggested in the literature *(see table 3.60)* which were not highlighted or discussed by the respondents in Study 1. It was found that respondents only focused on the interventions which were specific to their own hospital setting or their own experiential knowledge of ASPs. Furthermore, respondents indicated that their ASPs were at different stages of development in their hospitals. For example, some respondents indicated that due to financial constraints, they were only able to spend approximately 70% of their time on antimicrobial duties. As a consequence, the time spent to the development and implementation of interventions for AMS was very limited. Additionally, they were unable to monitor the effectiveness of current interventions as required as part of their AMS practices.

The evidence base has identified a number of interventions *(see section 1.10.4 to section 1.10.6)* which could be used to promote AMS in hospitals. It was found that the hospitals represented in Study 1 did not utilise each intervention as indicated by the literature so therefore respondents only focused on the interventions they use in their current post or in previous posts. These interventions such as antimicrobial cycling or rotation may not have been exclusively targeted by questions within the ASAT. However, they will be signposted as potential additional interventions for implementing AMS in future iterations of the ASAT *(see Appendix XXVII)*.

Table 3.60: Interventions not directly discussed or addressed by antimicrobial pharmacists in cognitive interviews (Study 1)

PROFESSIONAL INTERVENTIONS		
Intervention	Definition	Rationale for exclusion in ASAT v16
Care pathways[327]	A care pathway is *'anticipated care placed in an appropriate time frame, written and agreed by a multidisciplinary team'*. It has locally agreed standards based on evidence where available to help a patient with a specific condition or diagnosis move progressively through the clinical experience. It forms part or all of the clinical record, documenting the care given. It facilitates and demonstrates continuous quality improvement. It includes patient milestones and clinical interventions noted on the day or stage that they are expected to occur.	The efficacy of care pathways in AMS was supported by weak evidence base. The studies highlighted in the Cochrane review were CBA studies with a medium risk of bias and an ITS study with a high risk of bias. Also, the literature review conducted prior to Study 1 did not locate any high quality studies supporting this intervention.
Local opinion leaders Clinical champions	Use of providers nominated by their colleagues as *'educationally influential'. (see table 1.9)*	This intervention was reported as complementary to educational interventions. The evidence base supporting this intervention was equivocal and studies showed no change or a moderate change in practice.[156;159]
Reminders	Patient or encounter specific information, provided verbally, on paper or on a computer screen, which is designated or intended to prompt a health professional to recall information. This would usually be encountered through their general education; in the medical records or through interactions with peers, and so remind them to perform or avoid some action to aid individual patient care. Computer aided decision support and drugs dosage are included.	At the time of the study, computerised decision programmes or e-prescribing were not routinely used in the hospitals included in Study 1. Respondents indicated that they little or no experience of computerised reminders. Also, the evidence was limited evidence supported this intervention. Also, respondents reported that prescribers had a tendency to circumvent reminders or ignored reminders in some instances.

Table 3.60*(cont'd)*: Interventions not directly discussed or addressed by antimicrobial pharmacists in cognitive interviews (Study 1)

PROFESSIONAL INTERVENTIONS		
Intervention	Definition	Rationale for exclusion in ASAT v16
Therapeutic substitution or interchange[328]	Therapeutic interchange is defined as the dispensing of a drug that is therapeutically equivalent to but chemically different from the drug originally prescribed by a physician or other authorised prescriber. Although, usually of the same pharmacologic class, drugs appropriate for therapeutic interchange may differ in chemistry or pharmacokinetic properties, and may possess different mechanism of action, adverse-reaction, toxicity, and drug interaction profiles.	There were no high quality RCTs identified in the literature which investigated the effectiveness of this intervention. The evidence supporting this intervention included one CCT study with medium to high risk of bias.[126]
Automatic stop orders	Antimicrobial drugs may have clinical staff-approved automatic stop times as stipulated by guidelines. The pharmacist will notify physician of impending discontinuation of order the day before automatic stop. Unless the physician reorders the medication (or specifies duration of therapy in order) the medication will be automatically discontinued.	There was limited evidence in the literature to support the effectiveness of this intervention. Additionally, some respondents indicated that there were not in favour of automatic stop orders because they could potentially negate clinical judgement.
Rapid detection and susceptibility testing[329]	Susceptibility testing is used to confirm susceptibility to chosen empirical antimicrobial agents, or to detect resistance in individual bacterial isolates.	There was no high quality RCTs identified in the literature which investigated the effectiveness of this intervention. The evidence supporting this intervention was subjected to medium to high risk of bias.[178-181]
Novel biomarkers[185-187]	Infection markers are mediators of the inflammatory cascade and concentrations can be triggered by both infective and non-infective stimuli. The concentrations of these markers can also be influenced by toxic and tissue damaging processes	At the time of the study, respondents did not indicate that this intervention was used in their hospitals. There appears to be some evidence in the literature regarding the effectiveness of biomarkers in guiding prescribing decisions and reducing treatment duration. [330]

3.7.1.8 Modifications to the layout of ASAT v15a

In response to the verbal reports provided by the respondents in Study 1, there were modifications made to the layout of ASAT v15a and was included in ASAT v16. These modifications were conducted to resolve the cognitive difficulties reported by respondents.

An introduction was included in ASAT v16 which included an overview and principle functions of the ASAT. A brief description of the development of the ASAT and a brief description of ASAT domains were provided. A brief paragraph providing advice to NHS Trusts on how to prepare for ASAT completion and also instructions on how to complete the ASAT was provided in the introduction. In order to resolve temporal problems, a time period was specified for an ASAT evaluation.

In order to facilitate an intuitive question flow, there were sub-headings inserted into the ASAT and questions were grouped according the sub-headings *(see table 3.60)*. Questions which were measuring were grouped together and included with the sub-sections of ASAT v16. This was conducted in order to aid respondents to identify linked questions.

Domain and question numbering were also conducted to improve the clarity of the ASAT. The insertion of Appendix 1 into ASAT v16 which included a list of available guidelines on AMS as some respondents indicated that this could be used as a reference and help with completing the ASAT.

Table 3.61- The sub-headings inserted into ASAT v16

No.	Domain	New sub-headings
1	**Antimicrobial management within the Trust**	Antimicrobial stewardship
		Antimicrobial stewardship committee
2	**Operational delivery of the antimicrobial strategy**	Antimicrobial policy
		Antimicrobial guidelines
		Antimicrobial formulary
4	**Clinical governance and audit**	Antimicrobial consumption
		Clinical audit meetings
5	**Education and training**	Optimal antimicrobial prescribing
		Competency assessment
7	**Patients, carers and the public**	During patient admission
		During patient discharge

Domain and question numbering were also conducted to improve the clarity of the ASAT. The insertion of Appendix 1 into ASAT v16 which included a list of available guidelines on AMS as some respondents indicated that this could be used a

reference and help with completing the ASAT. As previously discussed in *section 3.11.1.1*, a glossary of terms was included in ASAT v16 in order to resolve comprehension problems.

3.7.1.9 Development of additional domain for clinical microbiologists

One of the key issues raised by respondents was there was limited examination of the role of clinical microbiologists in ASAT v15a. Respondents indicated that they felt that the role of staff group was crucial to the success of their hospitals' ASPs. They recommended that there should be a dedicated section which specifically examined the roles and responsibilities of clinical microbiologists. These recommendations agreed with the findings of the literature review conducted prior to the start of this programme of work. It was found that clinical microbiologists led several effective interventions in hospital-based ASPs. Consequently, seven draft questions *(see table 2.5)* were proposed for inclusion into ASATv16 based on the findings of the literature review. Cognitive interviews were conducted using these questions in Study 2 and the results of these interviews are discussed in Chapter 4.

3.7.2 Potential limitations of Study 1

The results of cognitive interviews should be interpreted with caution due to the limitations associated with this method. Firstly, one of the main assumptions of cognitive interviewing is that respondents will vocalise each cognitive difficulty they encounter when completing a questionnaire. One limitation of this study therefore, is that respondents may not report reliably about difficulties along the cognitive processing pathway. The researcher was reliant on the respondent ability or willingness to report cognitive difficulties experienced with ASAT v15a. Also, some questions may require thought processing which may be too quick or too complex to verbalise. Respondents may have utilised more than one cognitive model when responding to questionnaires. For example, for simpler questions respondents may use the Four Stage Model[255] where they sequentially process the question in order to generate answers. Alternatively, for more difficult questions respondents may use the Flexible Processing Model[248] where respondents may revisit preceding stages along the cognitive processing pathway to answer questions.

Another limitation of this study was the small sample (n=8) used to test the content validity of ASAT v15a. Every effort was made by the researcher to obtain a sample which was representative of the intended end-users of ASAT v15a. Also, the researcher endeavoured to attain multiple responses for each question within ASAT v15a hence improving the internal validity of Study 1. This small sample size could limit the generalisability of the study to other settings because each respondent was employed by a NHS trust within the Northwest SHA. Therefore, sampling bias could have been introduced in the study because respondents were chosen from the Northwest SHA only and also were members of one staff group involved in AMS. Respondent bias could have been introduced into the study due to the homogenous sample of respondents. However, these results could be considered illustrative and indicative of problems which other antimicrobial pharmacists may encounter when facilitating hospital-based ASPs and also completing the ASAT.

Similar to other studies which used cognitive interviews to validate questionnaires, comprehension and interpretation of questions appeared to be the most commonly reported difficulty. [331;332] This result is to be expected in the early stages of questionnaire development where they may be disparities between the questionnaire developers' intent and the interpretation by respondents. However, it is anticipated that applying cognitive interview methodology should improve questionnaires by identifying problems with cognitive processing of questions.

3.7.3 Conclusion

This programme of work involved an iterative process of validation of the ASAT based in the definition of validity proposed by Messick *(see section 2.1.3)*, which states that testing validity is the accumulation of evidence to support validity arguments.[217] It was clearly demonstrated from the analysis of the verbal reports in Study 1 that further modifications and validity testing were required. Further testing was required due to the modifications made to ASAT v15a to examine whether these modifications improved the validity of the ASAT. Also, the proposed section examining the roles and responsibilities of clinical microbiologists in ASPs needed to be tested with this staff group. The results of the subsequent validity studies are discussed in chapter 4 to chapter 6.

CHAPTER 4:

The investigation of the content validity of ASAT v16

4 INTRODUCTION

Chapter 3 presented the findings for the first qualitative study which investigated the content validity of ASAT v15a. This study represented the first stage of the sequential exploratory strategy used in this programme of work. From analysis of the verbal reports obtained from the cognitive interviews conducted with AMPs, it was found that ASAT v15 contained terminology and phraseology with limited the respondents' ability to generate responses to questions. These problems reported at each phase of the cognitive processing pathway. Other reported problems included question duplications, double-barrelled questions which primarily stemmed from cognitive difficulties. Irrelevant key concepts and/or questions were as a result of these concepts and/or questions not being relevant to current practices for example policies and guidelines were available via trusts' intranet site and not paper-based. Respondents also commented on the weightings and scoring of the response options in ASAT v15a and also other considerations regarding their local trusts' practices. The ASAT weightings and scoring were investigated using Rasch modelling and these results are presented in Chapter 5. Modifications were made to the ASAT in order to resolve the problems reported by respondents in Study 1. These modifications were primarily target at resolving comprehension problems as it was the most commonly reported problem. Modifications to the ASAT v15a included insertion of instructions, word or phrase substitution, merging or splitting questions where appropriate and also a glossary was inserted. These modifications were used to produce ASAT v16 *(Appendix IX)*. Also, a proposed domain was developed which examined the roles and responsibilities of clinical microbiologists *(see table 2.5)*. This was developed in response to the feedback from antimicrobial pharmacists about the coverage of the ASAT of other key staff groups involved in their trusts' ASPs. These views were supported by the findings of the literature review conducted prior to the initiation of this programme of work.

Chapter 4 presents the findings from the second qualitative study which investigated the content validity of ASAT v16. This study represented the second stage of the sequential exploratory strategy *(see figure 2.1)* used in this programme of work. This chapter presents an overview of the findings from the interviews conducted with clinical microbiologists. Each interview was conducted in two stages. The first part of the interview was a cognitive interview utilising the proposed domain for clinical

microbiologists. The second part of the interview was a semi-structured interview utilising ASAT v16 where respondents commented on the relevance of each domain of ASAT v16 and also provided general feedback on ASAT v16. The findings from this study were used to make modifications to ASAT v16 in order to produce ASAT v17. The rationale for conducting modifications to ASAT v16 is also discussed as well. These modifications were used to improve the content validity *(see section 3.1)* ASAT by addressing the identified problems with item or question design and also the overall instrument. The findings from these interviews are reported in two sections, the first section *(see section 4.5.1)* reports on the results from the cognitive interviews and the second section *(see section 4.5.2)* reports on the commentary on ASAT v16.

4.1 AIMS

- To evaluate the content validity of the proposed section for clinical microbiologists
- To determine whether the proposed section for clinical microbiologists should be included in ASAT v17
- To evaluate the content validity of ASAT v16

4.2 OBJECTIVES

- To determine the content validity of the proposed domain for clinical microbiologists by conducting cognitive interviews with this staff group utilising the draft questions for this domain
- To determine the content validity of ASAT v16 by conducting semi-structured interviews with clinical microbiologists
- To revise ASAT v16 using the findings of the content validity study, in order to produce ASAT v17

4.3 PARTICIPANT DEMOGRAPHICS

4.3.1 Demographics of clinical microbiologists

Clinical microbiologists were the target staff group for this study. This staff group were chosen because they had AMS as part of their job description. A total of 10 clinical microbiologists were recruited for Study 2. Five male and five female clinical microbiologists participated in this study with an age range between 32 to 58 years.

These clinical microbiologists were employed by their hospitals from a period of 4 years to 32 years *(see table 4.1)*.

Table 4.1- The types of hospitals and clinical microbiologists included in Study 2[324]

Respondent number	Trust type	Number of clinical microbiologists	Number of years in post*	Number of beds*
1	Foundation Acute	4	26	850
2	Acute	5	32	1047
3	Foundation Acute	4	9	890
4	Foundation Acute	2	29	583
5	Acute	3	28	641
6	Foundation Acute	5	31	737
7	Foundation Acute	3	32	748
8	Foundation Acute	3	24	728
9	Acute	1	27	677
10	Acute	1	4	395

*Nb. These data were collected during Study 2. The number of beds and years in clinical microbiologist post were accurate as of November 2011**

4.4 Methods

There were three main reasons for the inclusion of clinical microbiologists in Study 2. Firstly, the findings from the literature review conducted prior to the start of this programme of work showed that clinical microbiologists or clinicians with specialist knowledge of infection management were intervention leads in 32 studies. They were either the primary intervention lead (n=18) or as part of a multidisciplinary team (n=16). Secondly, the respondents in Study 1 indicated that the role of clinical microbiologists in ASPs needed to be examined in greater detail future iterations of the ASAT. Thirdly, clinical microbiologists have specialised training infection management and also they have a sound knowledge of clinical microbiology operational procedures such as infection diagnostic procedures.

As previously discussed, based on the findings of the literature and also guidelines which have been published on the role of clinical microbiologist in ASPs, seven draft questions for the ASAT were proposed which would examine their role *(see table 2.6)*. These questions were used to conduct cognitive interviews with clinical microbiologists in this study.

Qualitative data were obtained from clinical microbiologists using both cognitive interviews and semi-structured interviews. These interviews were conducted from June 2011 to November 2011. A total of 10 clinical microbiologists were interviewed for this study. Each interview was composed of two stages *(see section 2.3.10)*. The first stage involved conducting cognitive interview utilising the draft questions from

the proposed domain for clinical microbiologists. The second phase involved conducting semi-structured interviews utilising ASAT v16. Each interview was digitally recorded and transcribed verbatim.

Data analysis was conducted on the transcribed interviews using a thematic framework *(see section 2.2.10.7)* based on the Four Stage Model *(see section 2.2.10.5.1)* and also Flexible Processing Model for survey interaction *(see section 2.2.10.5.2)* for the cognitive interviews. A thematic framework *(see section 2.2.10.7)* was also used to analyse the semi-structured interviews. These interviews are not cognitive in nature so therefore there were analysed to identify emergent themes. However, no cognitive processing model was applied to the analysis of these interviews.

4.5 RESULTS

As previously discussed, the results of Study 2 have been reported according to the type of interview conducted with respondents. Section 4.5.1 presents the findings from the cognitive interviews and these findings have been presented at the question level. Section 4.5.2 presents the findings based on the general commentary on ASAT v16 also section 4.5.3 presents a discussion regarding the respondents' views on the proposed domain for clinical microbiologists.

4.5.1 Cognitive interviews (Proposed domain for clinical microbiologists)

4.5.1.1 Comprehension problems

Comprehension problems were reported by respondents in response to the proposed draft questions on the roles and responsibilities of clinical microbiologists in ASPs. This was the only cognitive difficulty reported by respondents and these are discussed in this section.

Table 4.2 - Draft question 1 (Proposed domain for clinical microbiologists)

Draft question 1	
1	**Is there a clinical microbiologist on your hospital's antimicrobial stewardship committee?[15;18]**

In response to the draft question 1 *(see table 4.2)*, most respondents indicated that they were able to comprehend the phrase *'antimicrobial stewardship team'*. However, one respondent reported that they were unclear of what was meant by this phrase, this was a comprehension-inclusion/exclusion problem. One respondent

commented, '*I am not quite sure what you mean by antimicrobial stewardship committee, we have a Drugs and Therapeutics Committee and the subgroup of that is our Antibiotics Sub-group'* (CM7). However, this respondent eventually correctly identified the group within their thrust that carried out similar duties to an antimicrobial stewardship committee. Respondents indicated that they used different terms to name the antimicrobial stewardship committee such as 'antimicrobial management team' (CM2), '*Clostridium difficile* Management Team' (Interview 4), 'Trust Antimicrobial Committee' (CM7) and 'Antimicrobial Sub-group' (CM10). They indicated that these teams or committees were generally composed of clinical microbiologists, pharmacists, clinicians, infection control nurses and in some instances, senior management, junior doctors and medical students. One respondent stated that their team was only comprised of microbiologists because their hospital currently did not have an antimicrobial pharmacist in post. The attendance of the Director of Infection Prevention and Control (DIPC) was *ad hoc* because they were usually members of the hospital's Trust Board. Respondents indicated that the frequency of team meetings was either weekly or monthly.

Table 4.3 - Draft question 2 (Proposed domain for clinical microbiologists)

Draft question 2	
2	**Are clinical microbiologists within your hospital involved in the development of antimicrobial policies and guidelines?**[4;18]

Most respondents indicated that they were able to understand to draft question 2 *(see table 4.3)*. One respondent indicated that they viewed antimicrobial guidelines as their trust formulary and commented *'Yeah, so our Trust formulary is developed by the antimicrobial management team…'* (CM10) and this was another example of a comprehension-inclusion/inclusion problem. Respondents indicated that the guideline development process was either led by the clinical microbiologist or by the antimicrobial pharmacist. The main triggers for the development of new guidelines or guideline updates were the publication of new evidence in the literature, results from antimicrobial audits, version control and AMR data. However, they indicated that these AMR data were not the primary trigger for revising or developing new guidelines.

The consultations with senior clinicians during the antimicrobial guideline development process helps with *'buy-in'* or support for antimicrobial treatment

guidelines. Respondents indicated that they have observed a higher compliance to guidelines which have been developed in conjunction with clinicians from other medical specialties.

Table 4.4 - Draft question 3 (Proposed domain for clinical microbiologists)

Draft question 3	
3	**Are antimicrobial resistance trends used to inform the content of antimicrobial policies and guidelines?[4;15;21;22]**

There were no cognitive difficulties were reported by respondents in response to draft question 3 *(see table 4.4)*. Respondents indicated that they may use AMR data to inform the content of their antimicrobial guidelines, one respondent commented, *'Very much so, that's what we base it on, we look at all the data that we are generating from the lab and based on the organisms' sensitivity patterns, we devise or modify our guidelines accordingly [pause] so we look at them'* (CM5). However, some respondents expressed concern about the quality of these data. They suggested that it was very difficult to extrapolate laboratory bench data to *'real world'* prevalence of infections. These data may not be truly reflective or representative of the hospital's ecology. They indicated that antimicrobial susceptibility data were subjected to sampling bias and were therefore potentially highly skewed. One respondent commented, *'There are all sorts of problems with antimicrobial susceptibility data when it's aggregated because when its data you get in the laboratory [pause] it's highly skewed'* (CM9).

Sampling bias occurred in hospitals because laboratory bench data were only representative of highly selected patients. This was due to the possibility that samples may not be taken in a proportion of patients, who were responsive to antimicrobial therapy, one respondent commented, *'They are [pause] not enough. We haven't used them extensively and the reason for that is data quality. We don't have sufficient benchmarks to determine what we need to use to modify these guidelines so even very simple things like empirical therapy for uncomplicated UTIs, it's not a simple thing to extrapolate susceptibility of the commonest organisms to the commonest antibiotics between formulary or the guidelines because this needs a lot of interpretation'* (CM6).

Table 4.5 - Draft question 4 (Proposed domain for clinical microbiologists)

Draft question 4	
4	**Are clinical microbiologists involved in the development of antimicrobial formularies?[18]**

In response to draft question 4 *(see table 4.5)*, comprehension- inclusion/exclusion problems were reported by two respondents. One respondent indicated that they were unsure of what the term *'formulary'* meant, they commented,

'When you mean formularies [pause] I mean, we have antibiotic guidelines and I am never quite sure exactly what a formulary is and what's the difference between a formulary and a guideline [pause] I think that probably the pharmacists may know [pause] Rightly or wrongly I think that the formulary is the list of antibiotics that are available' (CM7). This respondent correctly identified and defined the meaning of this term after re-reading the question.

Another respondent interpreted the *'antimicrobial formulary'* as an *'antimicrobial guideline',* they commented,

'I guess our antibiotic guideline is called our antibiotic formulary [pause] well what I refer to as our formulary is all the specific guidelines relating to specific conditions and which antibiotics we would recommend [pause] then we have an antibiotic policy which outlines the standards for antibiotic prescribing [pause] so the choice of the antibiotic, the dose, documentation of the indication and that sort of thing and we have a restricted antibiotic list within that policy and it's that antimicrobial team that developed the policy. Our formulary is more of a guideline [pause] it's a list of drugs that we would recommend for each condition [pause] so it's a bit of blurring of terms'(CM10).

Respondents indicated that they did not view formulary development as a standalone process and suggested that this question should be merged with draft question 3, *'Are clinical microbiologists within your hospital involved in the development of antimicrobial policies and guidelines?'*. One respondent commented, '*Yes we are, but we don't consider the development of the antimicrobial formulary as a separate distinct process. It generally follows on from antimicrobial guideline development'* (CM8). Some respondents indicated that they should have more input into the development of the antimicrobial formulary and stated that there are different approaches to influencing the content of the formulary. Firstly, by liaising with their antimicrobial stewardship committees or equivalent committee or secondly, by liaising with their hospital's formulary working group. However, one respondent indicated that they did not advocate the development or use of antimicrobial formularies. They viewed their development as solely the responsibility of the pharmacy department, they commented, *'the formularies are sort of secondary issue*

from my perspective [pause] I am not much of an advocate of formularies [pause] it's more of a pharmacy thing I think' (CM9).

Table 4.6 - Draft question 5 (Proposed domain for clinical microbiologists)

Draft question 5	
5	**Are clinical microbiologists involved in antimicrobial ward rounds?[18;22]**

There were no cognitive difficulties were reported by respondents in response to draft question 5 *(see table 4.6)*. Respondents indicated that they had both formal and informal ward rounds. They stated that formal rounds would consist of AMPs, specialist pharmacists, infectious diseases clinicians and junior clinical staff, where necessary. This type of ward round was structured and occurred daily. Informal ward rounds were not as multidisciplinary as formal ward rounds and these occurred on *ad hoc* basis primarily due to the availability of relevant staff. Formal antimicrobial ward rounds were conducted in critical care areas such as intensive care and high dependency units. Generally, they were conducted at a higher frequency than in non-critical care areas. One interviewee commented,

'Yes we do and there are hospital-wide not just for critical care areas [pause] so for the critical care areas we have them three times a week and for the non-critical care areas [pause] we may have four ward rounds a week. The composition on each ward round may be different due to availability but its generally one clinical microbiologist, one antimicrobial pharmacist per ward round, sometimes our SpRs may go on them instead of us. Also, in terms of the pharmacy involvement, we have approximately 50% of the time an antimicrobial pharmacist would be there and then sometimes it's an ICU pharmacist for critical care ward rounds, sometimes other specialist pharmacists would attend as well. This helps to build experience across specialities [pause] there isn't a total dependence on the antimicrobial pharmacist. We have found that collaborative working like this works best for us' (CM6).

Overall, respondents reported that the composition of the antimicrobial round was usually multidisciplinary with representation from clinical microbiology, pharmacy and other clinical staff.

Table 4.7 - Draft question 6 (Proposed domain for clinical microbiologists)

Draft question 6	
6	**Is the reporting of antimicrobial susceptibility testing results in line with formulary choices?[19;21;22]**

There were no cognitive difficulties were reported by respondents in response to draft question 6 *(see table 4.7)*. Respondents indicated that they would only report the sensitivities of the antimicrobials that were in the antimicrobial formulary, one respondent commented, *'Yes, what we put on our reports is entirely driven by what we want people to use so we use selective reporting. We may test with a panel of six or twelve antimicrobials but we would normally only report three or four [pause] the ones that the formulary would say that should be used for that type of infection, that applies to both the hospital sector and primary care. We don't offer drugs that we don't want people to use'* (CM 9).

Table 4.8- Draft question 7 (Proposed domain for clinical microbiologists)

Draft question 7	
7	**Is your hospital actively involved in surveillance or monitoring of antimicrobial resistance trends?[5;18]**

There were no cognitive difficulties were reported by respondents in response to draft question 7 *(see table 4.8)*. A number of respondents indicated that their hospitals were actively involved in monitoring AMR trends. They indicated that they participated in national mandatory data submissions of *C.difficile*, MRSA and more recently ESBLs.

Additionally, respondents indicated that they needed to be aware of AMR patterns locally, so that they can make any required changes to antimicrobial guidelines. One respondent commented, *'In addition to that, they are other aspects such as horizon scanning, having an idea about what's coming so that you can put things in place, seeing resistance patterns as they emerge and being aware of those to see whether you to make any changes to your existing guidelines'* (CM1).

However, some respondents were currently not involved in any European surveillance projects such as the European Antimicrobial Resistance Surveillance System (EARSS). One respondent commented, '*Well, I mean we submit all the data we have to national bodies such as the Health Protection Agency and the target schemes like C.difficile, MRSA and E.coli bacteraemias, we report through the HPA Co-serve system which used to certainly catch antimicrobial data. We are not involved in the more pan-European schemes because they tend to go to the larger teaching hospitals, neither are we involved in the European EARSS scheme* (CM9).

However, respondents indicated that locally, surveillance was problematic due to

poor IT systems within their hospitals, which subsequently led to poor data collection. However, respondents indicated that they had a good awareness of the problematic organisms within their hospitals.

4.5.2 Semi-structured interviews (ASAT v.16)

The respondents' views on ASAT v16 will be discussed below in this section. This section discusses the respondents' feedback on each ASAT domain within ASAT v16 and both positive and negative feedback will be discussed. The recommendations provided by respondents regarding improvements for ASAT v16 will also be discussed.

4.5.2.1 Domain 1: Antimicrobial management within the Trust

Respondents indicated that they believed that it is necessary to have a section examining the antimicrobial management structures within hospitals. One respondent commented, *'I guess in terms of antimicrobial management…it's quite comprehensive. It talks about who is on the team, who is on the committee and who do they report to.'* (CM10). However, respondents suggested that Q1.5, *'How often does the antimicrobial stewardship committee or equivalent meet?'* needed modifications in order to become a better quality indicator of ASPs. They suggested that in its current format, this question would not add value to an AMS evaluation because it utilised '*meeting frequency'* as a quality indicator. The ASAT assumed that a committee that regularly met had a greater impact on AMS than a committee that met less frequently. They suggested that a better indicator of quality would be the composition of the antimicrobial stewardship committee. Trusts should endeavour to have influential, senior level members such clinical directors that had decision making capacity within their organisations in terms of AMS.
Respondents suggested that Q1.8 *'Does the Trust Board receive a report pertaining to antimicrobial stewardship?'* was a non-specific question because some hospitals may produce reports which included AMS but not specifically addressing AMS only. Their hospitals would report on infection control and prevention statistics, drug usage and other related clinical audit activities. Respondents indicated that further clarification was required regarding the contents of an AMS report. They queried whether the report should be a stand-alone report or incorporated with another report

such as an infection control report. However, they generally agreed that an AMS report should be sent to the each hospital's trust board.

4.5.2.2 Domain 2: Operational delivery of an antimicrobial strategy

Respondents indicated that Q2.6 *'Are peer-reviewed, evidence-based guidelines available for the treatment of common infections?'* and Q2.7 *'Are peer-reviewed, evidence-based available for common procedures?'*, were very necessary and should be included as part of a hospital AMS evaluation.

Respondents indicated that they generally wrote their hospital's antimicrobial policies and guidelines to reflect local priorities, one respondent commented, '*We make sure that policies are kept up to date and that the whole strategy is directed and pushed forward according to the needs here [pause] Writing policies is the other bit, we are constantly reviewing the antibiotic formulary for the trust so most sections get reviewed by several pharmacists, microbiologists and specialists from the relevant areas for example for sexually-transmitted infections we would get a GU specialist to have input'* (CM3).

However, two respondents queried what was meant by the term *'peer-review'*, that is, did the term refer to national, regional or local peer review. These respondents suggested that the term *'peer review'* should be clearly defined, within the glossary of the ASAT.

Other respondents appeared to understand the term peer review and indicated that they believed that peer review of antimicrobial guidelines should compulsory. They expressed concerns about hospitals that produce their guidelines internally without any external peer review. They suggested that peer review of antimicrobial guidelines should be conducted by other microbiologists outside of the hospital in order to facilitate a robust and credible peer review process. One respondent commented,

'What I am very keen on [pause] we need to do much more of this is [pause] 'are the guidelines peer-reviewed?' So it's not only are clinical microbiologists writing the guidelines but as well [pause] 'Is there someone independent outside the Trust maybe another clinical microbiologist from another Trust, reviewing the guidelines?' This might be a good indicator because it would stimulate the idea that peer review is important [pause] each individual trust can't go ahead and do their own thing because of their local personal feelings about how things should be done' (CM6).

This respondent suggested that Q.2.6 and Q2.7 could be rewritten as *'are your locally produced guidelines, which are produced by clinical microbiologists and colleagues, peer reviewed outside your trust?*
Another respondent agreed that there should be active peer review of antimicrobial guidelines in both primary care and secondary care settings. They suggested that antimicrobial guidelines should be peer reviewed by microbiologists to ensure consistency of antimicrobial prescribing across care settings. One respondent commented,
'When I was going through this, I realised that you don't have anything in here anything about outpatient antimicrobial therapy or anything about prescribing in the community. What a lot of people don't realise is that prescribing in hospitals effects prescribing in the community and vice versa. You have patients coming and going across both care settings [pause] there are not distinct. I think that the same people should be reviewing antimicrobial guidelines for both primary and secondary care. We must be able to influence prescribing in the community so that hospitals can improve stewardship'. (CM10)

One respondent indicated that they did not believe that Q2.21 '*Are there antimicrobial ward rounds?'* was not a sensitive question because it did not possess the ability to distinguish between hospitals with effective and ineffective ward rounds. One respondent commented,
'*Just thinking of that question [pause] what does that mean? If you ask a trust which has 2500 beds, are there antimicrobial ward rounds and they say yes [pause] once a week and you ask a trust which has 300 beds the same question and they say yes, once a week [pause] those answers are very very different so I am not sure about it. But if the answer is yes, once a week and you've got eight critical care areas, that's not a very good service, but for a hospital with one critical care area [pause] then that's a good service. It's not a very sensitive question [pause] I have zoomed in on that as a single question, I am not sure if that's a useful question'* (CM2).
This respondent suggested that the phrase *'antimicrobial ward rounds'* needed to be clarified. They indicated that they were unsure of what type of ward round constituted an antimicrobial ward round and they commented '*Is a ward round considered an antimicrobial ward round because there is a clinical microbiologist present or if an infectious disease physician is present?'* (CM2). The respondent indicated that they

considered any ward round where there is input from either a clinical microbiologist or an infectious disease physician, an antimicrobial ward round. They suggested that Q2.21 should be changed to '*Are there ward rounds where the primary role is to discuss antimicrobial agents and are those ward rounds attended by clinical microbiologists?*'

4.5.2.3 Domain 3: Risk assessment for antimicrobial therapy

Respondents indicated that this domain was acceptable and did not suggest that any modifications were required to this domain. Respondents agreed that there was a need to reinforce the message about the necessity of therapeutic drug monitoring for high risk antimicrobials.

4.5.2.4 Domain 4: Clinical Governance Assurance

Respondents indicated that this domain was acceptable and did not suggest that any modifications were required; one respondent commented, *'I think that the audit questions are all relevant'* (CM10).

Most respondents indicated that they conduct antimicrobial-related audits regularly in order to monitor compliance to antimicrobial treatment guidelines. These audits were part of a rolling audit programme such as antimicrobial -specific, disease-specific, ward-specific, point prevalence audits or alert audits, one respondent commented, *'when wards have a certain level of C.difficile cases, it triggers an antimicrobial audit. In addition to the rolling programme of audits, we have alert audits as well so the antimicrobial pharmacists will go in and audit the antimicrobial prescribing over the week. The rolling programme looks at prescribing for chest infections, UTIs etc. and guideline audits [pause] the alert audits are triggered by the trigger wards [pause] the alert audits are coordinated by the infection control team, they analyse the data and feed it back to the directorates'* (CM1). Respondents indicated that antimicrobial audits should be clinically led in order to have a positive impact on AMS, one respondent commented,

'The other way to do it is to have an annual programme of prescribing audits which have to be driven clinically [pause] it's not going to be just pharmacists and clinical microbiologists. They measure themselves against good prescribing behaviour and more specifically how they perform against their own guidelines. You get negatives

and positives out of that process. The negatives are dealt with and then you re-audit them [pause] so that's what we do well' (CM6). However, they suggested that compliance to antimicrobial surgical prophylaxis guidelines was not audited routinely. All antimicrobial audits results were fed back to medical directors, divisions, directorates, wards and also to relevant clinical teams via quarterly or monthly audit meetings. Additionally, results were fed back to trust boards, clinical governance committee, drugs and therapeutics committee and as well as the antimicrobial stewardship committee.

Respondents indicated that they have developed evidence-based antimicrobial prescribing indicators and checklists for their prescribers, one respondent commented,

'We have developed an antimicrobial prescribing checklist and a review bundle. These cards were developed in-house based on the key principles on quality prescribing. The audits are conducted on the five principles stated on the cards such as documenting the indication and rationale for antimicrobial therapy, including any clinical criteria relevant to the patient, documentation of the patient's allergy status, compliance with antimicrobial guidelines in terms of choice and clinical criteria e.g. CURB score, documentation of the management plan including stop date or review date, any consideration given to drainage of pus or surgical debridement or removal of foreign material [pause] we are big on quality here. Now, with the production of 'Start SMART and then FOCUS' which is a checklist for secondary care prescribers [pause] we were thinking of adapting our local checklist' (CM8).

Respondents indicated that they have ensured that antimicrobial prescribing indicators have become part of their Trust Board's quality dashboards or scorecards, one respondent commented, *'The quality indicators have become part of their trust board's score card so there is an antimicrobial stewardship target and monthly compliance is recorded and monitored'* (Interview 8) and another respondent commented, *'We have a certain amount of feedback through a dashboard, it's in development at the moment but we have corporate and directorate dashboards which are reviewed in performance management meetings and with managers that run those parts of the hospital and all the main committee receive dashboard data'* (CM9)

Also, some hospitals reported that they have developed in-house electronic audit and feedback tools in order to communicate compliance to antimicrobial guidelines,

one respondent commented, '*and the e-auditing system which facilitates rapid feedback of the audit results has been quite beneficial to us [pause] part of the audit checks to see if the prescriptions are clinically appropriate'* (CM8). Respondents indicated that viewed electronic audit tools and quality indicators as being beneficial to ASPs because any breach in targets especially for *C.difficile*, MRSA bacteraemias and device-related bacteraemias, catheter related infections would be discussed with the prescriber. This practice ensured that prescribers would take more ownership of their prescribing decisions and the audit results could be used as a powerful tool to influence senior clinicians, one respondent commented,

'Every time you talk to senior doctors at meetings...if you can show trends, you can show that we are getting better. We have an ongoing slot in each quarterly audit meeting to report back to medicines, orthopaedics, general surgery, the trends and that's quite powerful' (CM7).

4.5.2.5 Domain 5: Education and Training

Respondents indicated that providing education on prudent antimicrobial prescribing to antimicrobial prescribers was one of the most effective ways to change antimicrobial prescribing practice. One respondent commented,

'It can be said that the more important role of the clinical microbiologist is actually out on the wards doing stewardship rounds, doing antibiotic ward rounds and doing clinical microbiology ward rounds. They would say that's where the clinical microbiologist makes the most impact. You have to have all these things in place in the laboratory, but you have to go out and challenge, teach and change practice out there' (CM7).

Respondents indicated that providing clinical advice to prescribers was a significant part of their role in ASPs. They indicated that they provide advice in both primary care and secondary care settings. One respondent commented, *'We have alot communication between ourselves and the clinicians on the wards, and general practitioners in the community, so we give alot of antibiotic advice'* (CM3). They viewed themselves as an essential technical resource on both patient care and antimicrobial therapy related issues, one respondent commented,

'I mean, if you want to know who has the biggest impact on how antimicrobials are used in hospitals, it would be the clinical microbiologists because the other doctors within the trust recognise that you are a doctor as well and understand inherently

what patient care is about because most of us have done it in our careers before we have become microbiologists. We are the sole group in the hospital that could bridge the gap between the technical drug related issues and the patient care issues because that's our job' (CM9).

However, respondents indicated that they were a number of problems relating to some of the questions in domain 5 *(see table 4.9)*, such as the format of the response options (CM3), collating the data required to answer this section (CM4) and also comprehension problems such as difficulty in understanding the phrase *'continuous education'* (CM6).

Respondents indicated that the response options of the questions in domain 5 *(see table 4.9)* were inappropriate because not many hospitals could provide detailed data on the percentage attendance for training programmes. They suggested that the response options should be collapsed into either two categories such as between 0% to 49% and 50% to 100% or alternatively to yes/no options.

Table 4.9 - Questions 5.4 to Q5.16 (ASAT v.16)

No	Question
5.4	**Is an annual update in safe and effective AM prescribing mandated for all prescribers?**
5.5	**Is an annual update in safe and effective AM prescribing available for all prescribers?**
5.6	**Is an annual update in safe and effective AM prescribing mandated for all pharmacists?**
5.7	**Is an annual update in safe and effective AM prescribing available for all pharmacists?**
5.8	**Is an annual update in safe and effective AM prescribing mandated for all staff who administer AMs?**
5.9	**Is an annual update in safe and effective AM prescribing available for all staff who administers AMs?**
5.10	**Do all staff who prescribe AMs receive annual training in safe and optimal use?**
5.11	**Do all staff who administer AMs receive annual training in safe and optimal use?**
5.12	**Do all staff who dispense AMs receive annual training in safe and optimal use?**
5.13	**What proportion of Foundations Year doctors attend training on safe and effective AM prescribing?**
5.14	**What proportion of registrars or specialist trainees attends training on safe and effective AM prescribing?**
5.15	**What proportion of consultants Year doctors attend training on safe and effective AM prescribing?**
5.16	**What proportion of NMPs Year doctors attend training on safe and effective AM prescribing?**

Respondents indicated that they would have difficulty in collating the data necessary to complete this section. They indicated that most hospitals would use both formal and informal methods to educate and train their prescribers about optimal antimicrobial prescribing. The formal method of training would be usually conducted at induction to foundation year doctors where they would be given an overview of antimicrobial therapy and signposted to the relevant guidelines and policies. Capturing data on attendance at induction could be relatively straight forward because they can access sign-in sheets or registers to determine the attendance at the training sessions. Also, some respondents indicated that they used e-learning packages as part of their trust induction process. Informal training usually occurs on the wards at the point of care and conducted on an *ad hoc* basis. Some respondents indicated that they viewed providing clinical advice to antimicrobial prescribers as part of an informal education process. Capturing data on informal training on antimicrobial prescribing would be very difficult for hospitals to collate and report because records of these types of sessions would not be formally recorded. One respondent commented,

'There were issues around attending training where a lot of training would be done informally. Yes, the formal training is easy to assess who has done it because they would have to submit feedback forms and you have your sign in sheets as well. A lot of education around infection control and antibiotic stewardship is done on the wards. We would go out and see patients and educate at that point' (CM4).

However, respondents agreed that there was a need for continuous education on optimal antimicrobial therapy due to changes in antimicrobial susceptibility patterns. However, they indicated that precisely defining continuous education would be difficult. One respondent commented,

'Continuing education is a very difficult, nebulous concept. When we have been under intense pressure, we have produced an antimicrobial quiz online and it took about ten minutes to fill in. We got everybody to fill it in so or continuing education was greater than ninety percent. Did they become good prescribers with heightened awareness of antimicrobials as a consequence? Not sure...but we had assurance that they have received training. Defining the quality of continuing education would

be tricky...defining what people would need at different levels would be difficult' (CM6).

Other issues regarding Q5.4 to Q5.9 *(see table 4.9)* were raised by respondents such as the frequency of updating antimicrobial prescribers and in Q5.10 to Q5.16 (*see table 4.9)* in terms of training on optimal prescribing. In response to Q5.4 to 5.9 *(see table 4.9)*, one respondent disagreed with the frequency of updates in optimal antimicrobial therapy, they commented,

'Is there an annual update on optimal prescribing mandated or available for the following staff groups? Why annual? Why would it be annual? What's magic about 365 days? Has someone done some research that your decay in knowledge about how to prescribe decays at a rate that is has to updated every 365 days, why not every 1000 days? Why annual? Why not 10-yearly? There is just an assumption here that refreshing has to be done on an yearly basis, what does that have to do with your knowledge about antimicrobial prescribing?' (CM2).

In response to Q5.10 to 5.16 *(see table 4.9)*, respondents indicated that training in optimal antimicrobial prescribing may be covered in other training on drug therapy or medicines management training, therefore it would be difficult to produce figures on attendance, one respondent commented,

'What proportion attend training on optimal antimicrobial prescribing?' Again, what if you deliver your training under another umbrella? For instance, you may have an optimal prescribing session and in it they talk about heart drugs, emergency drugs like noradrenaline, antimicrobials and other types of drugs... but that may not be an optimal antimicrobial prescribing session…it wouldn't be badged as such but it would deliver the same thing...so how would you answer this question? Can anyone answer these questions? Can they give actual figures? (CM2). Another respondent commented, *'In terms of the percentages…if we have gone out and delivered the training on the wards… how would we calculate that? I guess it depends on how definitive an answer you want… do you want an approximation or estimation or do you want actual number'* (CM10).

It was suggested by respondents that a clear definition regarding the training on optimal antimicrobial prescribing is required, the ASAT would need to specify the content of the training packages and how the training should be delivered, one respondent commented,' *… it would probably be useful to get more information*

about what sort of information is given so whether it's a formal lecture or whether its e-learning or hand-outs or booklets… whether its paper-based information' (CM10).

4.5.2.6 Domain 6: Antimicrobial Pharmacist

Generally, respondents indicated that some questions in domain 6 were appropriate for examining the role of the antimicrobial pharmacist. Respondents indicated that they believed that the introduction of the antimicrobial pharmacist posts, which were as a result of the Hospital Pharmacy Initiative (HPI) has been beneficial to their ASPs, one respondent commented, *'I think that one of the biggest changes over the years has been the introduction of antimicrobial pharmacists, I think that has made a huge difference'* (CM3). Respondents indicated that they have viewed the antimicrobial pharmacist as having a positive impact on the quality of antimicrobial prescribing and the overall management of antimicrobials, one respondent commented,

'…we viewed it very much as something that would help us to improve the quality of our antimicrobial prescribing and management within the trust [pause] we knew that would be the case because the post was part-time and only a few hours were stretched across two big hospitals, it would be very difficult to set in place a strategy for saving money but we did feel that we made some quality improvements [pause] difficult to translate some of those into actual money' (CM1). Respondents indicated that when the initial funding from the HPI was exhausted, they explored other sources of funding from infection control to fund future posts. On respondent commented, *'when the money came for antibiotic pharmacists, we were ready and we said that we want this. When the money dried up, the post was so important that the head pharmacist managed to arrange things so that we kept that post'* (CM7). Due to the positive impact of the antimicrobial pharmacist posts on ASPs, most hospitals indicated that they currently had antimicrobial pharmacists on staff or were in the process of recruiting antimicrobial pharmacists.

Table 4.10 - Question 6.3 (ASAT v16)

No	Question
6.3	**How many *whole time equivalent (WTE)** antimicrobial Pharmacy staff per 500 beds are spent on antimicrobial duties?**

In response to Q6.3 *(see table 4.10)*, they suggested that the pharmacy staff to bed ratio is not reflective of an AMP's workload in AMS, one respondent commented, *'The number of beds specified as well, doesn't quite capture workload [pause] it may be different if you are a DGH versus a teaching hospital [pause] an acute trust with a high academic workload needs more antibiotic pharmacists than a DGH. I can't suggest a metric for capturing that data'* (CM6). In order to improve the sensitivity of Q6.3, respondents recommended that there should be a recognition that hospitals differ in their specialisms, remits such teaching, bed numbers and dedicated antimicrobial staffing. Workload can vary depending on these factors and would be unique to each antimicrobial pharmacist therefore using it as a generic indicator decreased the sensitivity of this question.

Table 4.11 - Question 6.4 (ASAT v16)

No	Question
6.4	**Does the lead *antimicrobial pharmacist** have >3 years experience in this specialist role?**

Also, in response to Q6.4 *(see table 4.11)*, they queried the rationale of using the number of years in specialist role for the antimicrobial pharmacist as a quality indicator, one respondent commented, *'One thing I didn't like about this section was the pharmacist's qualifications…it seems to be more of a survey rather than a quality indicator…'Does the lead antimicrobial pharmacist have greater than 3 years experience in this specialist role?' Why not 2 years etc.?'* (CM6). Respondents were unable to understand the rationale of greater than 3 years as a benchmark of quality. They suggested that the ASAT was assuming that hospitals with antimicrobial pharmacists with greater than 3 years experience were more effective at AMS than hospitals with less experienced antimicrobial pharmacists.

4.5.2.7 Domain 7: Patients, Carers and the Public

Respondents indicated that they generally agreed that this section was necessary in an evaluation of AMS in hospitals. They indicated that the data required for this section would be difficult to collect because the information given to patients was not recorded. However, they suggested that after an evaluation with the ASAT, hospitals may use these questions as part of their clinical audits programmes. This would be done to evaluate the quality of patient information about prescribed antimicrobials. One respondent commented,

'What I really like about this is this section even though it may be the hardest to complete. I think that everyone will score zero on this area! I am not sure if these questions are good questions to ask [pause] but that fact they are being asked is going to be a driver for quality improvement and safety. Even for us [pause] we are looking at this and saying to ourselves [pause] we don't do this! I particularly like this because we haven't thought of this. It's a good example why a particular exercise like this will stimulate improvement in stewardship in Trusts. People will find gaps like this and address them' (CM6) and another respondent commented ''*I am not sure how good we are at that but it's obviously very important'* (CM7).

Respondents agreed with the importance of informing patients about the antimicrobials they have been prescribed and ensuring that patients have understood the information. They indicated that this was necessary because patients need to become more informed about their antimicrobial medication history. This is especially important because if patients they have any subsequent hospital admissions, they would be able to provide hospitals with the antimicrobial medication histories. One respondent commented,

'It's interesting explaining to patients about the reasons why they have been prescribed antibiotics and why there are used [pause] maybe this needs to be specific about how that information is given whether its telling them that there are having an antibiotic and make sure they know which antibiotic they are having and what indication it is and how long they take it for because you come across so many patients that come into hospital and say that they had an antibiotic wouldn't have an idea of what the name of it was or why they were taking it or when they stopped taking it so probably most of the time prescribers think that the patient understands what they are taking and quite often that is not the case so further information on exactly what you would like would be helpful' (CM10).

Respondents indicated that they were keen to ensure that all patients on antimicrobials fully understood the reasons the antimicrobials were prescribed and the necessity of completing the course of antimicrobials.

'Yes, I agree that these are the questions that we should be asking ourselves especially for patients that have been on antimicrobials before...they need to remember the name of the antimicrobial and how long they have been on it for. The problem is that we can say yes, the patient have been informed of the drugs that

they are on [pause] however do we really know if they have digested and comprehended the information they we have given them [pause] even if it's written information. How would we confirm a patient's understanding of the antimicrobials they have been given? Maybe the question should be [pause] has the patient been given written information about the antimicrobial that have been prescribed? Hospitals may score themselves 100%, but is this accurate [pause] because they assumed that this has happened [pause] but is this correct?'(CM10).

A proportion of respondents indicated that they could score 100% for these questions because there was written information about antimicrobials on prescription boxes; therefore hospitals could report that information had been given to patients. However, there were currently no systems in place to ensure that patients understand information given to them by prescribers.

4.5.2.8 General commentary on ASAT v16

Respondents were asked to provide general commentary on the content of ASAT v16, for example its relevance and comprehensiveness in evaluating AMS in hospitals. Generally, respondents were generally positive about the ASAT and its content, one respondent commented,

'Overall, I am very very positive about this toolkit. We were so impressed with this, we have used this with our primary care partners with our CQUIN data, we have assigned ourselves a number using this toolkit and we have agreed to improve the number using this metric because we have an objective way of measuring it. We have confidence in this process' (CM6).

Respondents indicated that they thought that the ASAT v16 was a very comprehensive document which targeted the key aspects of AMS in hospitals. One respondent commented, *'I think that it's a good self-assessment tool, it's quite comprehensive and it covers most of the aspects which we would want because of the governance, risk assessment...all of those things are important'* (CM5). Also, they reported that the ASAT v.16 was very easy to complete because it was in a checklist format where most of the questions had yes/no response options, one respondent commented, *'We felt that we fulfilled most of these and we were able to answer reasonably straightforwardly, it was good that they were 'yes/no' options'* (CM4).

However, respondents they stated that some questions were difficult to interpret, one respondent commented, *'I think that it does cover the main aspects of stewardship in trusts, but the main issue we found were interpretation issues of some questions'* (CM4).

Respondents highlighted that there were some negative aspects to ASAT v16. Firstly, respondents indicated that they felt that the ASAT v16 only examined systems and processes used by hospitals in ASPs but the toolkit does not investigate any compliance to antimicrobial-related strategies, policies and guidelines. One respondent commented, *'In terms of the general sub-section headings [pause] Yes, it does cover the main things. It's a huge wish list, isn't it? The ASAT asks whether these things are covered in policies and guidelines but the main thing is whether these things are being done in hospitals* (CM1).

Respondents were asked to comment on the length of the ASAT v16 and even though they agreed that it covered the key aspects of AMS, they indicated that they felt that the ASAT v16 was too lengthy. One respondent commented, '*the fewer questions on this, the better [pause] it's a fairly bureaucratic process to answer each question is [pause] you might be put off actually!'* (CM2).

Respondents suggested that only evidence-based questions should be included within the ASAT v16 because these questions could be classed as standards. These standards could be used by hospitals as part of their clinical audits or evaluations of service provision relating to AMS. They suggested that all questions which have been included due to consensus expert opinion should be excluded from the ASAT v16 because these questions would not have a good evidence base. One respondent commented,

'Having these questions in a self-assessment tool suggests it's an audit [pause] and these are standards [pause] these are not standards. Once it gets into the public domain and the report goes to the CQC then they start comparing trusts against one another. They become standards and you will be compared with people when there is no need to be…' (CM2).

Respondents indicated that they were concerned that the questions within the ASAT will become compulsory standards of care in AMS and that these standards will be used to compare the performance of hospitals against each other. One respondent commented,

'You are effectively saying the trust needs to be doing this all the time. If we score badly on it, we would then need to change our practice and that practice change is based on someone decided what they meant by an antimicrobial ward round [pause] that is not an evidence based process. We would then get a letter from CQC saying that this trust doesn't do enough antimicrobial ward rounds. We would then have to focus on other care areas excluding haematology etc [pause] the perspective you are getting from me is that I am the infection prevention and control doctor for the trust so I am exposed to information requirements that come to us and I am constantly faced with this situation' (CM2) and another respondent commented, *'My only concern is that it can be used by 'the powers that be' such as the Department of Health. It may come across as a list of 'must dos' for hospitals, instead of just being an overview of good practice'* (CM8).

Respondents indicated that ASAT v16 should clearly stipulate the evidence required by hospitals to demonstrate compliance to the questions within ASAT v16. One respondent commented,

'You need to put in something there about guidance regarding the quality of evidence that is required to produce an answer for each question for example does the committee meet regularly? You would to submit the minutes and the people who attended the meetings [pause] the quality of the group that meets? You would need to submit the terms of reference and the composition or breakdown of the group' (CM6).

4.5.3 Commentary on the proposed domain for clinical microbiologists

This section focuses on the respondents' views regarding the inclusion of a designated section for clinical microbiologists. In response to the question, *'What do you think of the coverage of the role of clinical microbiologists ASAT v.16?'* respondents indicated that there were positive and negative aspects to including a dedicated section for clinical microbiologists.

Respondents indicated that they believed that they were the most appropriate staff group to lead ASPs in their hospitals. They indicated that ASPs would be deficient and non-effective unless they are led by clinical microbiologists, one respondent commented, *'These are more coherent bringing together of those elements plus others that would make you think that you are looking for a leadership role for a*

microbiologist for most antimicrobial stewardship programmes, if that's missing the programme would be impoverished substantially and it will carry less clout' (CM9).
Non-medical staff leadership of ASPs was usually done by antimicrobial pharmacists or infection control nurses and respondents indicated that the knowledge base of these staff groups about AMS was inadequate, one clinical microbiologist commented,
'The problem is that you would find in most Trusts that the DIPC role isn't done by a clinical microbiologist, it's done by a nurse, or by a medical director or by people who have no insight into infections or antibiotics [pause] that's a problem sometimes. I am a DIPC as well, but there is another DIPC who is a gynaecologist, and she has dedicated some of the role to me. In most cases, it's done by nurses, so it may not be what you want it to be [pause] they are not the right people to be leading stewardship' (CM5).

Most respondents indicated that they were not in agreement with the coverage of their role within the ASAT v16. One respondent commented,
'When I did glance through it [pause] that thought occurred to me. It's not an isolated incidence of that problem, there seems to be a blind spot in the Department of Health that clinical microbiologists actually exists. They send out missives to people that clearly impact on what we do daily and we are not included in the circulation processes or those things which is not the way to engage a key group of staff. I mean, if you want to know who has the biggest impact on how antimicrobials are used in hospitals, it would be the clinical microbiologists because the other doctors within the trust recognise that you are a doctor as well and understand inherently what patient care is about because most of us have done it in our careers before we have become microbiologists' (CM9).
Respondents provided a number of reasons that supported having a dedicated section that targets the roles and responsibilities of clinical microbiologists. They suggested that a dedicated section within the ASAT would provide a clear description of their roles and responsibilities in AMS, one respondent commented,
'Yes, there should be a section in there for us [pause] we currently don't have an antimicrobial pharmacist in this Trust so it would be important for us to have some kind of outline of the roles and responsibilities therefore I think it would be important to have a section dedicated for us [pause] we are currently putting together a

business case for an antimicrobial pharmacist. We have to justify our time commitment for antimicrobial stewardship [pause] so having it clearly laid out like this would be helpful' (CM10) and another respondent commented, *'I think that it would be useful to have a section for clinical microbiologists in the toolkit because if you could specifically identify roles and responsibilities that were defined'* (CM1). Respondents indicated that they believed the section is important in order reinforce that clinical microbiologists should lead ASPs. Respondents reported that their influence was essential to good AMS, specifically in terms of guideline development, one respondent commented,

'Yes, I think that those would be appropriate questions to ask [pause] 'Should a clinical microbiologist be involved with antimicrobial guidelines? Absolutely! I think without them, if it's just left to clinicians or pharmacists alone, these guidelines will be weak in the sense of not capturing the diagnostic efforts locally and the local data so I would strongly support them to be markers' (CM 6). Another respondent commented,

'I think that the questionnaire and the headings are ok [pause] just as long as you now add clinical microbiologists to it [pause] you should have an extra bit in there. I would be unhappy if there wasn't a section for clinical microbiologists. I would like you to have a section like you have here for antimicrobial pharmacists, saying 'clinical microbiologists' (CM7).

Respondents reported that sometimes they had to justify the amount of time they spent on antimicrobial duties and that currently, their job plans did not account for the amount of protected time required for effective AMS. One clinical microbiologist commented,

'It would help people seek funding from the trust, rather than it being an add-on job that you would have to do. If you said that there was a package of stuff that will take me half a day a week therefore if the trust wants me to do that they will have to give me that half day a week [pause] sometimes it's easier to have what you do defined, than rather it being this nebulous thing which can actually be a huge job but goes unrecognised by the trust or in your job plan so I think it would probably be useful' (CM1) and another respondent commented,

'Yes, I do think that there should be a dedicated section within the ASAT for clinical microbiologists and I guess to have something about how they do things. I think that clinical microbiologists know what their role should be but sometimes because of

equipment, time constraints, or the information available [pause] what we think our role is and what people's perception about what we are doing could be quite different. I think that those would be sensible questions to ask. It would provide a sort of field where by people could say that 80% of people have a system in place where they can survey their antimicrobial resistance trends monthly [pause] we haven't. It would give you a bit of evidence to go to your trust board and say we need a system like this' (CM4).

One interviewee suggested that a metric such as bed ratios was required for the time allocated for antimicrobial duties. This metric could be potentially used to identify whether hospitals have adequate clinical microbiologist support for the ASPs. *'...it's how you assess whether that is being delivered effectively. We don't spend 100% of our time on antimicrobial duties [pause] no microbiologist would do that but I think that you can come up with a rough idea the sort of allocation of time. We all have job plans which can be looked at and it would be very helpful to all microbiologists if someone did that piece of work and come up with an idea of what is a good time commitment.'* (CM9). This respondent suggested that a metric could be derived through consensus opinion from clinical microbiologist groups, similar to the process conducted for infection control nurses. One respondent commented, *It has been done for infection control and there are estimations about how much time should be available on infection control activities in a hospital [pause] depending on the size of the hospital. The Royal College of Pathologists have got guidance on that so it might well be possible to do that for antimicrobial leadership in the trust and give people an idea of what they should be trying to provide [pause] if it's not up to scratch then you would give them ammunition on bidding for extra resources from the medical microbiology side. You have that question about whole time equivalent pharmacists per 500 beds, that sort of thing [pause] I am sure it wouldn't be too difficult to get a consensus through the microbiologist groups about that'* (CM9).

However, two respondents did not agree that a section was unnecessary for clinical microbiologists because the general approach to AMS within their hospitals was multidisciplinary. Some roles and responsibilities in AMS would be covered by more than one person such as antimicrobial guideline development; therefore it was not

necessary to evaluate the role of the clinical microbiologist. One respondent commented,

'Depends on what you want to do with it really...all of the functions in the questionnaire needs to be done by someone or a group of people [pause] multidisciplinary team approach. The emphasis on who does what may not be necessary. A section on the clinical microbiologist may have similar responses across trusts. The clinical microbiologist would be involved in antimicrobial policy and guideline development and those responsibilities would be shared with the antimicrobial pharmacist' (CM8).

Another respondent agreed with interviewee 8, who suggested that a section would not be necessary. They stated that as long as the ASAT asked relevant questions about AMS then a section on clinical microbiologists would not be necessary. They indicated that they were uncertain that it was mandatory for microbiologists to be involved in all aspects of AMS, they commented,

'I don't see why it's necessary to have a dedicated section for clinical microbiologists as long as the document asks the right questions. Who says what the role of the clinical microbiologists should be? If you have a question in here saying, 'Does your antimicrobial guideline group meet and how often it meet? 'Does it always have to have clinical microbiologists' representation?', 'Does every guideline have contribution from for clinical microbiologists?' You are effectively saying those are the rules and those are the things to be followed. I am uneasy about it because when you start to write things down like this, they become the rules and the next thing is that you are assessed against them' (CM2).

4.6 DISCUSSION

The implications from the findings from Study 2 are discussed in this section of the chapter. An overview of the modifications are described in this section and a detailed description is provided in the modification table (ASAT v16 to ASAT v17) *(see Appendix XXV)*. This table contains the details of each modification made to ASAT v16 and also provides a rationale for each modification.

4.6.1 Implications on the development of the ASAT

There were modifications made to ASAT v16 based on the results of the interviews conducted in this study. Also, modifications were made resulting from discussions

with the supervisory team which included a member of ARHAI. Overall, there were five new questions added to the ASAT and there was only modifications made to one question *(see table 4.12)*. Also, there were modifications made to the instructions and the glossary of the ASAT v16 *(see Appendix XXV)*.

Table 4.12 -The process of development, testing and item reduction for ASAT v15a to ASAT v17[2]

Study type	Method	ASAT version	New	Retained	Modified	Deleted	Total
Qualitative	**Item construction** Consensus expert review and literature review (ARHAI)	**15a**	83	n/a	n/a	n/a	83
Qualitative (Study 1)	**Content validity** Cognitive interviews with antimicrobial pharmacists	**16**	2	25	58	4	85
Qualitative (Study 2)	**Content Validity** Cognitive interviews and semi-structured interviews with clinical microbiologists	**17**	5	85	1	0	91

4.6.1.1 Resolution of comprehension problems (cognitive interviews)

The findings from the cognitive interviews indicated that there was comprehension problems associated with three questions. These questions contained terms or phrases which were either difficult to understand or interpreted incorrectly by respondents. These phrases were *'antimicrobial stewardship committee'* (draft question 1 - see table 4.2), *'antimicrobial guidelines'*, *'antimicrobial policies'* (draft question 2 - see table 4.3), and also *'antimicrobial formulary'* (draft question 4 - see table 4.5). These findings reflect the findings in Study 1 where antimicrobial pharmacists had difficulty in interpreting these terms as the ASAT developers had intended. These results indicated that there is need for consensus definitions of these terms or phrases across staff groups.

As discussed in *section 3.11.1.1*, there was a glossary of terms included in ASAT v16. Each term which was identified by respondents in Study 2 had previously been defined in the glossary of ASAT v16. The findings from the cognitive interviews have

[2] *'New' represents questions that were developed from newly constructed questions including question merging. 'Retained' represents questions that remain unchanged. 'Modified' represents questions that were altered for example by conducting word insertions and word deletions*

emphasised the necessity for a glossary of terminology to be included in the ASAT and supports the inclusion of a glossary in future iterations of the ASAT.
Respondents suggested that measuring their involvement in the antimicrobial guidelines and formularies separately was unnecessary. This was because the antimicrobial formulary would be developed as a result of the recommendations within the antimicrobial guidelines. They suggested that the draft question measuring their involvement in antimicrobial formularies should be included in further iterations of the ASAT. Therefore, it was decided not to add this question to the proposed section for clinical microbiologists.

4.6.1.2 Resolution of problems identified from the semi-structured interviews

The findings from the semi-structured interviews indicated that respondents primarily agreed that ASAT v16 covered the most pertinent aspects of their hospital's ASPs. However, they recommended that there should be modifications to some of the questions in ASAT v16, in order to improve question sensitivity, hence reducing measurement error of the toolkit. Other recommendations to improve ASAT v16 were made by respondents however these were mainly derived from local hospital specific issues.
Respondents indicated that there should be a domain which examined the antimicrobial management structures within NHS Trusts. Respondents provided recommendations for two questions in Domain 1 and there were Q1.5 and Q1.8. Respondents recommended that meeting frequency should not be used as an indicator of quality for Q1.5. They reported a committee that met more frequently may not be more efficacious than a committee that met less frequently. However, on analysis of the literature supporting domain 1 *(see section 1.5)*, it was decided not to adjust the weightings of the response option for this question. The weightings of questions within the ASAT were examined during Rasch modelling and will be discussed in Chapter 5. Respondents indicate that they would like clarify on the contents of the annual AMS report that which should be sent to trust boards. However, it is the responsibility of each hospital's chief executive to sign off compliance to the Health and Social Care Act (2008) which contains a section on antimicrobial prescribing. Consequently, the content of AMS report would be

dependent on local settings therefore no guidance on the content was provided in future iterations of the ASAT.

Respondents indicated that they generally agreed with the content of Domain 2. Two respondents suggested that the term *'peer review'* used in Q2.6 and Q2.7 needed to be defined in the toolkit. However, it was decided that this did not need a definition since it was interpreted correctly by the majority of respondents. Some respondents indicated that they did not believe that Q2.21 was not a sensitive question because it lacked the ability to discriminate between effective and ineffective ward rounds. The primary function is to evaluate whether hospitals have structured antimicrobial ward rounds as part of their ASPs. The efficacy of ward rounds in promoting AMS locally is the remit of antimicrobial committees and other relevant staff groups. A definition of antimicrobial ward round has been previously included within the glossary of the ASAT so therefore no modifications were made to this question.

Respondents reported that it was very important to assess compliance to Domain 3 and indicated that the questions in this domain did not require any modifications.

Respondents reported that that were in agreement with the inclusion of Domain 4 within ASAT v16. They also reported that they have seen the benefits of clinical audit as part of their ASPs such as increased compliance to treatment guidelines, prescribers taking ownership of their prescribing decisions and also greater awareness of AMS within their hospitals. Respondents indicated that there were no modifications required for Domain 4.

Respondents reported that they viewed education and the provision of clinical advice as crucial components of their roles in ASPs. Subsequently, they indicated that the inclusion of Domain 5 was essential because they believed that education was vital to the success of ASPs. However, they highlighted that collating the data in response to this section would be challenging for hospitals, specifically, in terms of obtaining for continuous education attendance. These findings were similar to Study 1, where antimicrobial pharmacists indicated that it would be difficult to collate the data for Domain 5. However, on analysis of the evidence on educational interventions *(see section 1.4.2.2 and section 1.9)*, it seen that these interventions were effective in improving ASPs. Therefore, it was decided to retain these questions in their current format.

Respondents indicated that they viewed antimicrobial pharmacists as essential for the success of ASPs in their hospitals and agreed that this domain should be included within ASAT v16. However, they raised concerns regarding Q6.3 *(see table 4.10)* as they felt it did not adequately reflect the workload of antimicrobial pharmacists. Interestingly, this issue was not raised by antimicrobial pharmacists as they indicated that this question did not require any modifications. No modifications were made to Q6.4 *(see table 4.11)* although respondents raised concerns about the experience of antimicrobial pharmacists being used as a quality indicator for ASPs. However, respondents in Study 1 indicated that there were in agreement with this question and that it should not be modified.

Respondents reported that they felt that Domain 7 should be included in an evaluation of hospitals' ASPs. However, they did not indicate that the data would be difficult to collate as was reported by respondents in Study 1. They indicated that they could score 100% for these questions because the information required for patients to comply with the recommended antimicrobial therapy was written on the prescription box. No modifications were made to the questions in Domain 7 as it was felt that hospitals needed to improve on the quality of information given to patients about their prescribed antimicrobials.[333]

4.6.1.3 Inclusion of the proposed domain for clinical microbiologists

Respondents reported that they were unsatisfied for the coverage of their roles and responsibilities ASAT v16 because they indicated that it was not an adequate reflection of clinical microbiologists in ASPs. This was reported in both cognitive interviews and also the semi-structured interviews. The inclusion of the section for clinical microbiologists was therefore as a result of the findings of the interviews and also the literature review conducted prior to the start of this programme of work. The results of the literature review indicated that approximately 50% of interventions were led by this staff group or clinicians with specialist training in the diagnosis and management of infections. Consequently, the domain which examined the role of clinical microbiologists was included in ASAT v17 and was labelled as Domain 7 in ASAT v17. As a result, the domain labelled 'Patients, Carers and the Public' became domain 8 in ASAT v17.

4.6.2 Potential limitations of Study 2

To the researcher's knowledge, this is the first study to investigate the perspectives of clinical microbiologist in ASPs. This use of semi-structured interviews provided data on the views of clinical microbiologists on ASAT v16 but also the current status of ASPs in their health care settings. These data enabled the researcher to understand the processes that limit and those that enable the development of ASPs within NHS trusts. On analysis of these data, it was found that ASAT v16 addressed the pertinent aspects of ASPs and therefore was relevant to NHS trusts.

In Study 2, cognitive interviews were conducted using the draft section for clinical microbiologists. As previously discussed in *section 3.7.2*, the results of cognitive interviews should be interpreted with caution. The results indicated that comprehension problems were the most commonly reported difficulty. These findings reflect those obtained in Study 1.

As previously discussed, another limitation of Study 2 was due to the small sample (n=10) used to test the content validity of ASAT v16. Every effort was made by the researcher to obtain a sample which was representative of the intended end-users of ASAT v16. Also, the researcher endeavoured to multiple responses for each question within ASAT v16 hence improving the internal validity of Study 2. This small sample size could limit the generalisability of the study to other settings because each respondent was employed by a NHS trust primarily within the Northwest SHA (n=9). However, these results could be considered illustrative and indicative of problems which similar clinical microbiologists may encounter while completing the ASAT.

As previously discussed, other studies which used cognitive interviews to validate questionnaires reported that comprehension and interpretation of questions was the most commonly reported difficulty. This result is to be expected in the early stages of questionnaire development where they may be disparities between the questionnaire developers' intent and the interpretation by respondents. However, it is anticipated that applying cognitive interview methodology should improve questionnaires by identifying problems with cognitive processing of questions.

Due to the homogenous nature of the respondents, it was possible that respondent bias was introduced into Study 2 because these data were obtained from the interviews was from the perspective of clinical microbiologists only. In order to overcome this limitation, multidisciplinary focus groups could have possibly been

used to validate the ASAT. Additionally, it was possible that a form of acquiescence bias[256] occurred because clinical microbiologists would be in favour of easy questions and avoid questions which targeted processes which were labour-intensive challenging and more discriminating of clinical microbiology processes. Some of these challenging issues were not raised by respondents in either Study 1 or Study 2. A list of such possible questions is given below examining the role of clinical microbiologists:

- *Are antimicrobial resistance trend data for important drug-bacterium pairs reported at least annually by the laboratory?*
- *Does the laboratory provide interpretation of cultures from non-sterile sites?*
- *Does the laboratory reject specimens for non-sterile sites without documented evidence of infection?*
- *What WTE of clinical microbiologist resources are ring-fenced to support antimicrobial stewardship?*
- *Do clinical microbiologists follow-up all patients with clinical significant positive blood cultures on the ward?*
- *Do clinical microbiologist ward rounds take place in speciality areas at least once a week?*
- *Are serum concentrations of high risk antimicrobials measured on-site?*

Although, some of these points were not raised by study participants, these questions will be included in the recommendations for future research regarding the development of the ASAT.

4.7 CONCLUSION

This was the second study conducted in this programme of work which specifically aimed to examine the content validity of ASAT v16 and also to determine whether the domain for clinical microbiologists should be included within ASAT v17. The aims of this study were achieved because the respondents indicated that ASAT v16 measured the pertinent aspects of ASPs in hospitals and this can be seen from the verbal reports obtained. Also, the rationale underpinning the inclusion of a domain for clinical microbiologists was confirmed also by the verbal reports obtained in this study. Interestingly, Study 2 appeared to be confirmatory in nature because there were common issues raised with regard to some of the questions of the ASAT across the two studies. Both staff groups encountered difficulties when interpreting

specific terms and also both groups reported issues around collating data for the ASAT.

The subsequent study conducted in this programme of work specifically looked at investigating the construct validity of ASAT v17 which was conducted using Rasch modelling. The results of this study were used to develop further iterations of the ASAT and are reported in Chapter 5 of this thesis.

CHAPTER 5:

Investigation of the validity of ASAT v17 using Rasch modelling

5 INTRODUCTION

Chapter 4 presented the findings of the second qualitative study (Study 2) which investigated the content validity of ASAT v16. Study 2 represented the second stage of the sequential exploratory strategy used in this programme of work as part of the investigation of the unified concept of validity *(see section 2.1.3).* Chapter 4 presented an overview of the findings from the interviews conducted with clinical microbiologists. The analysis performed on the verbal reports obtained from these interviews conducted in Study 2 indicated that ASAT v16 required further minor modifications. Examples of the minor modifications conducted on ASAT v16 included an update of the introduction section of ASAT v16 and also moving one question from domain 2 to domain 7. The main modification to ASAT v16 was the inclusion of the domain that specifically targeted the role and responsibilities of clinical microbiologists. These modifications were conducted to further improve the validity of the ASAT and subsequently produce ASAT v17 *(see Appendix XIX)*.

Chapter 5 presents an overview of the findings of Study 3 represents the third stage of the sequential exploratory strategy used in this programme of work *(see figure 2.1)*. Rasch modelling *(see section 2.4.11.2)* was used to investigate the construct validity ASAT v17 and analysis was conducted at a sub-scale level and a scale level Due to the nature of Rasch modelling, these analyses conducted identified two main categories of items (item categorisation):

- items which were productive for measurement
- items which were unproductive for measurement

ASAT items which were productive for measurement had INFIT MNSQ within the range of 0.7 to 1.3 *(see table 2.9)* and possess the ability to discriminate between high and low performing trusts with the study sample. These items appeared to work well collectively at defining the construct under investigation at sub-scale (domain) level such as ‘Antimicrobial Management within the Trust’. On analysis of the entire item pool (scale level), items within the INFIT MNSQ range appear to work collectively to define the unitary construct of ASPs and therefore were considered as productive for measurement.

ASAT items which were unproductive for measurement lacked the ability to discriminate between NHS trusts. These items were categorised as overfitting or underfitting the PCM. ASAT items were categorised as overfitting if they had an

INFIT MNSQ less than 0.7 *(see table 2.9)* and were overly predictable. ASAT items were categorised as underfitting if they had an INFIT MNSQ greater than 1.3 *(see table 2.9)*. The analyses identified items where the PCM was unable to determine their difficulty due to NHS trusts achieving perfect (negative or positive) scores in response to these ASAT items.

This chapter is presented in three sections. *Section 5.5.1* to *section 5.5.8* presents the results of the Rasch modelling conducted on ASAT v17 by domain (sub-scale level). As previously mentioned, the analyses were performed for each domain (sub-scale level) separately and items were discussed in respect to their behaviour within the analysed construct or domain. Rasch modelling was unable to produce *'ability'* estimates for perfectly scored items in each domain and therefore WINSTEPS *'dropped'* from these items from analyses. The results obtained for each domain are presented and are accompanied by the rationale for item retention or item deletion, where appropriate. In some instances, the rationales have been derived primarily from the findings from the cognitive modelling in Study 1 and Study 2 conducted as part of the programme of work.

Section 5.5.9 to *Section 5.5.10* present the overall ASAT item pool in order to investigate whether the entire item pool defines the unitary concept of ASPs. *Section 5.5.11* presents the proposed item pool of ASAT v18 which would be productive for measurement if the ASAT were to be used as a benchmarking tool and includes the overall fit statistics and also the item/respondent maps for ASAT v18. The examination of the overall fit statistics was conducted to confirm whether the items in the proposed ASAT v18 operated as a single variable that measured ASPs in NHS trusts.

5.1 AIMS

- To investigate the construct validity of ASAT v17 by using Rasch analysis
- To produce ASAT v18 from the results of the Rasch analysis conducted on ASAT v17
- To investigate the construct validity of ASAT v18 by conducting further Rasch analysis

5.2 OBJECTIVES

- To collect quantitative data about the participating NHS trusts' antimicrobial stewardship programmes using ASAT v17
- To conduct Rasch modelling on the ASAT domains using the dataset produced by the responses from the participating NHS trusts. These analyses primarily included the examination fit statistics for each domain of ASAT v17
- To examine the overall fit statistics of ASAT v18 in order to assess the construct validity
- To modify ASAT v17 using the results of the fit statistics of each domain in order to improve and produce ASAT v18

5.3 PARTICIPANT DEMOGRAPHICS

NHS trusts were the main target group for this study. This type of healthcare organisation was chosen because the ASAT was designed to evaluate the interventions for used implementing ASPs in these care settings.

Participants were recruited from six strategic health authorities (SHAs) across England *(see table 5.1)* utilising the recruitment strategy as described in section 2.4.8. These SHAs were the Northwest SHA (n=23), Southwest SHA (n=4), Yorkshire and The Humber SHA (n=2), West Midlands SHA (n=2), Southeast Coast SHA (n=1) and the London SHA (n=1). The number of beds within these NHS trusts ranged from 81 to 1950.

Table 5.1 - The types of NHS trusts and their corresponding SHA recruited for Study 3[238;324]

Respondent number	Strategic Health Authority (SHA)*	Trust type*	Number of beds
1	North West	Foundation Acute	748
2	North West	Foundation Acute	81
3	North West	Foundation Acute	147
4	North West	Foundation Acute	662
5	North West	Foundation Acute	616
6	North West	Foundation Acute	890
7	North West	Acute	284
8	South West	Foundation Acute	628
9	South West	Foundation Acute	604
10	North West	Foundation Acute	728

*Nb. The allocation of NHS trust type and number of beds were accurate as of March 2012**

Table 5.1 *(cont'd)* - The types of NHS trusts and their corresponding SHA recruited for Study 3[238;324]

Respondent number	Strategic Health Authority (SHA)*	Trust type*	Number of beds
11	North West	Acute	717
12	North West	Foundation Acute	743
13	North West	Acute	284
14	North West	Acute	342
15	North West	Foundation Acute	1002
16	North West	Foundation Acute	683
17	Yorkshire &The Humber	Foundation Acute	1950
18	North West	Acute	707
19	South West	Acute	720
20	West Midlands	Acute	912
21	West Midlands	Acute	782
22	North West	Foundation Acute	583
23	North West	Foundation Acute	1484
24	North West	Acute	510
25	South East Coast	Foundation Acute	605
26	South West	Foundation Acute	390
27	North West	Foundation Acute	498
28	London	Foundation Acute	429
29	North West	Foundation Acute	1121
30	Yorkshire &The Humber	Foundation Acute	700
31	North West	Foundation Acute	917
32	North West	Acute	395
33	North West	Foundation Acute	174

*Nb. The allocation of NHS trust type and number of beds were accurate as of March 2012**

5.4 METHODS

Quantitative data were obtained from the 33 NHS trusts utilising ASAT v17 *(see table 5.1)*. Respondents were asked to complete the ASAT and to return the completed ASAT to the researcher. Most respondents (31/33) were antimicrobial pharmacists however there were two NHS trusts where the respondent was a clinical microbiologist.

Rasch modelling was conducted on the responses generated from ASAT v17 *(see Appendix XIX)* using Rasch modelling (PCM) *(see section 2.4.11.2)*. Subsequently, both the item (question) and respondent (NHS trust) fit statistics *(see section 2.4.11.3.1)* were examined to investigate how they fit the PCM.[302] There were three outputs from WINSTEPS which were analysed in Study 3. These were the items statistics, item/respondent maps and respondent statistics outputs *(see section 2.4.11.3.2)*. The INFIT MNSQ is a *t*-standardised information-weighted mean square statistic, which is more sensitive to unexpected behaviour affecting responses to items near the respondent's measure level.[306]

Table 2.10 - The parameters of the INFIT MNSQ values [230;306]

Value	Definition
>2.0	Off-variable noise is greater than useful information. Degrades or distorts measurement. Always remedy the large misfits first.
>1.3	Noticeable off-variable noise. Neither constructs nor degrades measurement. Unproductive for construction of measurement, but not degrading
0.7 to 1.3	Productive for measurement
<0.7	Overly predictable and are less productive for measurement. Misleads us into thinking we are measuring better than we really are. (Attenuation paradox). May produce misleading reliabilities or separations. Misfits <1.0 are only of concern when shortening a test

INFIT MNSQ values of 0.7 to 1.3 were categorised as productive for measurement, values less than 0.7 were overfitting the model, values greater than 1.3 were underfitting the model and hence introducing noise into the model *(see table 2.9)*.[230] The item/respondent output shows how the respondents (NHS trusts) were distributed by the items and was examined to identify hierarchy of NHS trusts. Also, this map provides a distribution from the highest scoring NHS trust(s) at the top to the lowest scoring NHS trust(s) at the bottom and also item hierarchy. The respondent (NHS trust) statistics output provided an estimate (or calibration) of NHS trust hierarchy. These values were reported in logits with two decimal places. If the score was extreme, the value was estimated, as MAXIMUM (perfect score) or MINIMUM (zero score).

The dataset generated from the ASAT responses was imported into WINSTEPS for analysis. Rasch modelling using the PCM was conducted in two stages as previously discussed. Firstly, each domain was analysed sequentially, that is, from domain 1 to domain 8. Secondly, Rasch modelling was conducted on all of the items in ASAT v17 collectively. Both of these stages were done to investigate item fit to the PCM. At each stage of the analysis, the three outputs produced by WINSTEPS were analysed. The item statistics output was the first output to be analysed. In instances where items received perfect scores from NHS trusts, these items were *'dropped'* from the analysis by WINSTEPS. In other words, due to nature of the PCM which is probabilistic in nature, Rasch modelling is unable to provide estimates for perfectly scored items. This is because the estimates are based on the probability of responding favorably or not responding favorably to items within the ASAT. These items lacked the ability to discriminate between NHS trusts and therefore there were interpreted by WINSTEPS as invalid observations. The INFIT MNSQ values for each

item was examined to verify if there were productive for measurement, that is, within the range of 0.7 to 1.3 *(see table 2.10)*. Misfitting items that is, underfitting (null or limited predictability) may indicate that the items are measuring a construct or dimension which is external to ASPs. Overfitting items (overly predictable) may indicate that NHS trusts are most likely to have the organisational process(es) or system(s) of implementation targeted by the item as part of their current practice or in other words, it was common practice across the study population. NHS trusts are able to respond favorably to the item so therefore overfitting items are unable to discriminate between NHS trusts. Underfitting and overfitting items were removed from the analysis and the remaining items were reanalysed to investigate whether their removal improved item fit of the domain under investigation. If the removal of these items improved the item fit of the domain (as indicated by the fit statistics) then there were retained for further analysis. The item/respondent maps outputs were examined to identify which NHS trusts hierarchy and item hierarchy. The respondent (NHS trust) statistics output was also examined to obtain NHS trusts estimates of '*ability*'.

Therefore, Rasch modelling was undertaken in order to investigate the unified concept of validity as described in *section 2.1.3*. This unified concept of validity is based on the premise that construct validity encompasses other validity sub-types such as content validity. The compliance to the assumptions of Rasch modelling that is, unidimensionality *(see section 2.4.11.2.1)*, local independence *(see section 2.4.11.2.2)* and item discrimination *(see section 2.4.11.2.3)* were investigated, in order to accumulate evidence for validity arguments. The rationale for item deletion or item retention was primarily based on the findings of Rasch modelling. Additionally, the underlying causes for misfit have been mainly supported from qualitative data derived from the previous studies (Study 1 and Study 2) conducted in this programme of work. These accounts are mainly based on the results of the previous qualitative studies (cognitive modelling) conducted in this programme of work based on the guidelines for instrument construction stipulated by Wolfe and Smith (2007).[274;277] These studies primarily focused on investigating the content validity of previous versions of the ASAT using cognitive modelling.

Based on these analyses and the qualitative evidence generated from Study 1 and Study 2, recommendations were suggested for items which should be retained or removed from the item pool of ASAT v17 in order to produce ASAT v18.

Consequently, the item pool of ASAT v17 was categorised into items which were productive and not productive for measurement based on the INFIT MNSQ ranges provided in *table 2.9*. Items which were productive for measurement normally had an INFIT MNSQ within the range of 0.7 to 1.3 *(see table 2.9)*. Items which were not productive for measurement had an INFIT MNSQ outside the range 0.7 to 1.3 or were perfectly scored (negatively or positively) by NHS trusts.

The next stage of the analysis was to examine the overall fit statistics (item and respondent statistics) for the proposed ASAT v18, which was composed of items which were productive for measurement. In other words, these items could be used for comparative analyses between NHS trusts.

5.4.1 Pre-analytical (technical) issues

As previously mentioned, the assumptions of Rasch models are unidimensionality *(see section 2.4.11.2.1)*, local independence *(see section 2.4.11.1.2)* and also item discrimination (*see section 2.4.11.1.3)*.

Each domain of ASAT v.17 was examined to identify if there were any questions that conflict with the assumptions of Rasch model and hence suitable for analysis within the Rasch Measurement Framework. These pre-analytical issues encountered were mainly questions containing operators such as *'and'*, *'or'* which measured more than one variable *(see table 5.2)*.

Table 5.2 - Questions containing operators such as *'and'* and *'or'*, which measured more than one variable

No.	Question	Response options
Q1.4	Does the Trust have an *antimicrobial committee** or equivalent accountable to the *Infection Control(IC)*/Drugs and Therapeutics Committee (DTC)**?	Y=1; N=0
Q1.5	How often does the *antimicrobial committee** or equivalent meet?	2 = > quarterly 1= quarterly 0= < quarterly
Q1.6	Does the *antimicrobial committee** or equivalent have minutes or an action list?	Y=1; N=0
Q1.7	Where do the minutes from the *antimicrobial committee** or equivalent go?	1= CG/IC/DTC or higher level 0= other committee
Q2.1	Does your Trust have an *Antimicrobial Policy** or section in another Trust policy that clearly states the overall principles of antimicrobial use?	Y=1; N=0
Q2.16	Is there an *Antimicrobial Formulary** or section within the Trust formulary?	Y=1; N=0

Table 5.2 *(cont'd)* - Questions containing operators such as *'and'* and *'or'*, which measured more than one variable

No.	Question	Response options
Q3.5	Are incidents of antimicrobial usage fed back to the antimicrobial committee or other group?	Y=1; N=0
Q4.1	Is there an *antimicrobial audit strategy** or programme?	Y=1; N=0
Q6.2	Is there an *antimicrobial pharmacist** actively in post or in the process of recruitment?	Y=1; N=0
Q7.6	Is advice from a clinical microbiologist/*infectious disease physician** available by phone?	2 = 24 hours 1 = working hours
Q8.2	How many patients or their legal guardians are usually informed that they have been prescribed an antimicrobial and the reason/s why antimicrobial is necessary?	3 = >80% ; 2 = 50 -79% 1 = 30 - 49% ; 0 = <30%
Q8.3	How many patients or their legal guardians are usually informed of the risks and side effects associated with antimicrobial treatment?	3 = >80% ; 2 = 50 -79% 1 = 30 - 49% ; 0 = <30%
Q8.4	How many patients or their legal guardians are usually informed that they have been prescribed an antimicrobial to take home and the reasons why an antimicrobial is necessary?	3 = >80% ; 2 = 50 -79% 1 = 30 - 49% ; 0 = <30%
Q8.5	How many patients or their legal guardians are usually informed of the course length and the importance of finishing the course?	3 = >80% ; 2 = 50 -79% 1 = 30 - 49% ; 0 = <30%
Q8.6	How many patients or their legal guardian are usually informed about possible risks and side effects of antimicrobials and what to do if side effects develop at home?	3 = >80% ; 2 = 50 -79% 1 = 30 - 49% ; 0 = <30%

These questions could violate one of the assumptions of Rasch modelling which is that each question or item should measure only one variable (item discrimination). However, after discussions with the chair of ARHAI, it was explained that these questions should remain in the analysis because it was important that NHS trusts had the processes targeted by these questions in place. Therefore, either response option provided by these questions chosen by NHS trusts was acceptable.

On examination of the response options of ASAT v17, it was observed that some needed recoding prior to data analysis. The recoding conducted to adjust for the previous weights for the response options which were conducted prior to the start of this programme of work. Rasch modelling assigns item hierarchy (item difficulty estimates) from the logit position on the latent variable under investigation. These logit positions can be observed on the item/respondent maps for each domain (*see section 5.5.1 to section 5.5.8)* and the overall item pool *(see section 5.5.9)* and are based on the ASAT responses (scores). In other words, Rasch modelling recommends item hierarchies based on ASAT responses. Instrument developers

could potentially use these hierarchies to weight ASAT items in further iterations of the ASAT. As a result, recoding were due to the absence of an assigned value for zero (n=11) and also where there were no incremental response options (n=5). Recoding was done to ensure that there was uniform frequency distribution between response categories for each question. A value for zero was assigned to response options where there was no value for zero *(see table 5.3)*.

Table 5.3 - Recoding conducted for response options where there was no assigned value for zero

Question	Original response options	Recoded response options
Q2.2	3 = prescription and notes 2 = prescription 1 = notes only	2 = prescription and notes 1 = prescription 0 = notes only
Q2.3	3 = prescription and notes 2 = prescription 1 = notes only	2 = prescription and notes 1 = prescription 0 = notes only
Q2.4	3 = daily 1 = every 48 hours	2 = daily 1 = every 48 hours 0 = not stipulated
Q2.6	2 = yearly 1 = every two years	2 = yearly 1 = every two years 0 = less than every two years
Q2.14	1 point assigned to each response option for choice, dose, route and IV switch	This is a special case which was discussed previously*
Q2.15	2 = yearly 1 = every two years	2 = yearly 1 = every two years 0 = less than every two years
Q2.21	2 = yearly 1 = every two years	2 = yearly 1 = every two years 0 = less than every two years
Q2.22	3 = greater than twice a week 2 = bi-weekly 1 = weekly	3 = greater than twice a week 2 = bi-weekly 1 = weekly 0 = less than weekly*
Q4.8	2 = less than annually 1 = annually	2 = less than annually 1 = annually 0 = greater than annually
Q6.3	3 = greater than 1.0 WTE 2 = 0.4 WTE 1= less than 0.4 WTE	2 = greater than 1.0 WTE 1 = 0.4 WTE 0 = less than 0.4 WTE*
Q7.6	2 = 24 hours 1 = working hours	2 = 24 hours 1 = working hours 0 = not available

For example, in Q2.2, which states 'Does the *Antimicrobial Policy** stipulate that indication should be recorded before antimicrobials are prescribed?' the response options are '*3 = prescription and notes*', *'2 = prescription'* or *'1 = notes'*, however there is no option for '0'. The recoding conducted on these questions is shown in table *(see table 5.3)*.

In instances where there were no incremental response options (n=5) or uneven distributions between response categories, these categories were recoded so that they would become evenly spaced (*see table 5.4)*.

Table 5.4 - Recoding for response options where there were no incremental response options (unequal distance)

Question	Original response options	Recoded response options
Q2.4	3 = daily 1 = every 48 hours	2 = daily 1 = every 48 hours 0 = not stipulated
Q2.7	3 = Yes 0 = No	1 = Yes 0 = No
Q2.8	2 = Yes 0 = No	1 = Yes 0 = No
Q2.9	2 = Yes 0 = No	1 = Yes 0 = No
Q2.10	3 = Yes 0 = No	1 = Yes 0 = No

5.4.2 Collapsing response categories

The PCM exhibits greater stability where there are three response options or less.[230] The response options for Q2.22 were collapsed so that there would be equal spacing between response options *(see table 5.5)*.

Table 5.5 - Recoding conducted after collapsing response options for Q2.22

Question	Original response options	Recoded response options
Q2.22	3 = greater than twice a week 2 = bi-weekly 1 = weekly 0 = less than weekly*	2 = greater than twice a week 1 = weekly 0 = less than weekly*

However, one of the main limitations of collapsing categories is that there is a potential data loss.

The dataset for Rasch analysis with WINSTEPS was created after item recoding was conducted *(see table 5.3 to table 5.5)*. In order to facilitate data analysis in WINSTEPS, an excel spreadsheet was created. This spreadsheet was populated with the responses for each question from each Trust (N=33). In instances where there were missing data fields, that is, where there were no responses given to questions by Trusts, the fields were denoted as either *'no data entered'* or *'missing data field'*. The code *'ND'* was entered for these fields.

5.5 RESULTS

The results of the analyses conducted on the ASAT are presented at a domain level that is, ITEM STATISTICS and NHS TRUST STATISTICS. Each output for NHS TRUST STATISTICS is not presented in this chapter. These outputs have been included in *Appendix XXIX*. In the context of Rasch modelling, fit statistics are indicative of how well the data fits the model. Consequently, the fit statistics, that is, INFIT MNSQ values of each domain were examined to determine whether there were either overfitting or underfitting the Rasch model.

5.5.1 DOMAIN 1 (Antimicrobial management within the Trust)

On examination of the item statistics for Domain 1*(see table 5.6)*, it was found that there were two questions which were underfitting in this domain and which were Q1.3 (INFIT MNSQ 1.35) and Q1.4 (INFIT MNSQ 1.63) which indicated that these items did not fulfil the assumption of unidimensionality. This INFIT MNSQ values indicated that Q1.3 and Q1.4 were working together well with the other items in domain 1 to define 'Antimicrobial Management within the Trust'. All other items, that is, items Q1.1, Q1.2, Q1.5, Q1.6, Q1.7 and Q1.8, fulfilled the assumption of unidimensionality, in other words, these items appear to be measuring the unitary concept of antimicrobial management within NHS trusts.

Table 5.6 - ITEM STATISTICS (DOMAIN 1 - ASAT v17)

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
1.1	26	33	1.12	0.51	0.86	-0.40	0.86	-0.30
1.2	32	33	-1.73	1.08	0.70	-0.20	0.13	-0.60
1.3	28	32	0.18	0.63	**1.35**	0.90	1.62	1.10
1.4	31	33	-0.84	0.83	**1.63**	1.10	1.66	0.90
1.5	50	31	2.43	0.46	0.96	-0.20	0.87	-0.30
1.6	30	31	-1.68	1.09	0.70	-0.20	0.14	-0.50
1.7	30	31	-1.68	1.09	0.70	-0.20	0.14	-0.50
1.8	21	33	2.20	0.44	0.88	-0.80	0.82	-0.60
Mean	31.0	32.1	0.00	0.77	0.97	0.00	0.78	-0.10
S.D	7.9	0.9	1.64	0.27	0.32	0.60	0.58	0.60

Nb. Misfitting items in Table 5.6 have been highlighted in blue.

The item/respondent map for Domain 1*(see figure 5.1)* showed the hierarchy of NHS trusts with respect to the ASAT items (questions) for this domain.

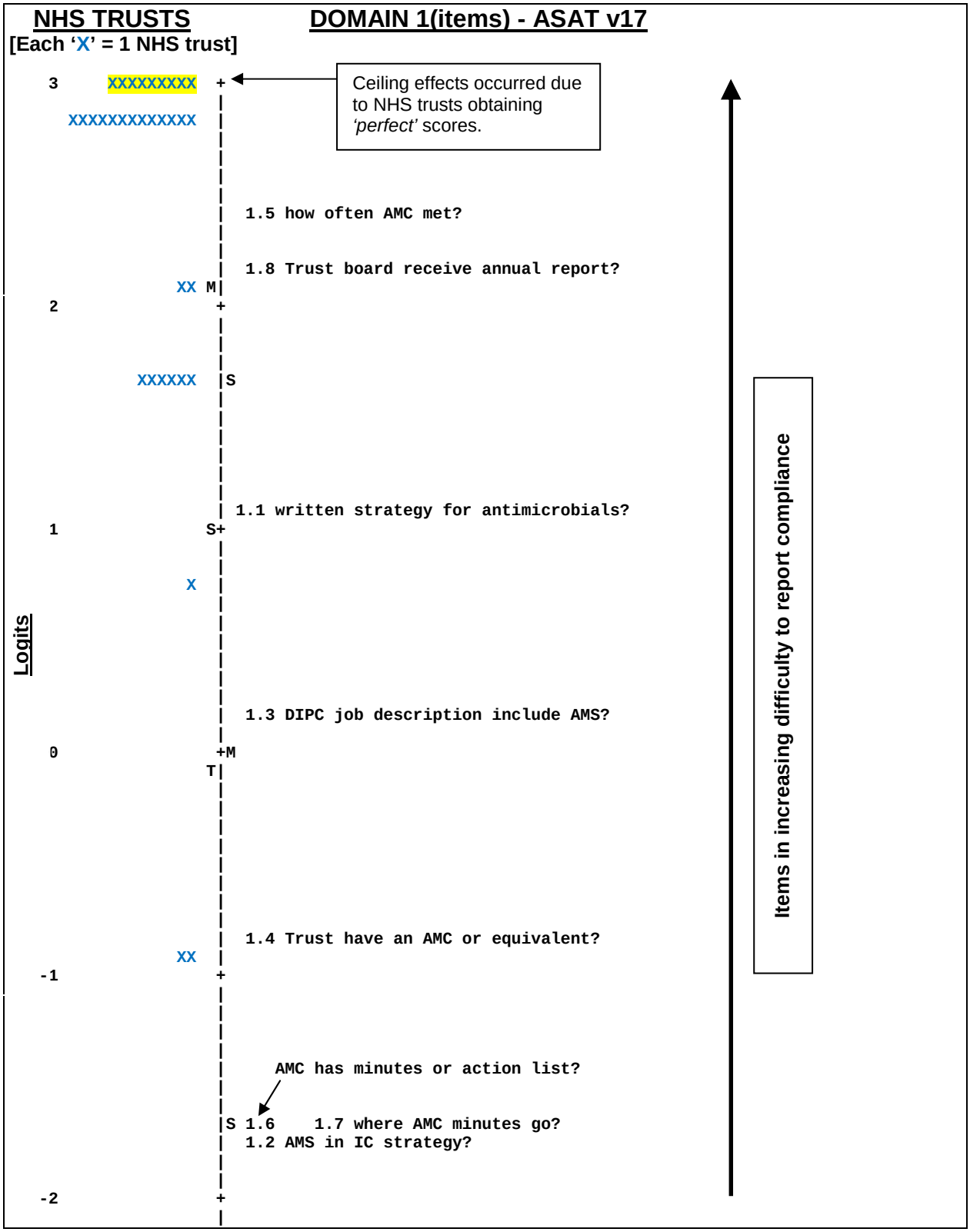

Figure 5.1 - Respondents/items map (Domain 1)

Nb. The abbreviations used in figure 5.1 are antimicrobial committee (AMC), antimicrobial stewardship (AMS), director of infection prevention and control (DIPC) and infection control (IC)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust

Q1.5 was the most difficult item for NHS trusts to indicate compliance and Q1.2 was the easiest item for NHS trusts to report compliance. In other words, NHS trusts achieving perfect scores for this domain (n=10) were skewed towards the top of the operational range for Domain 1. These perfect scores resulted in the ceiling effect in the item/respondent map. Also, there were a further 13 NHS trusts which were located near the top of the operational range. Therefore, 23 NHS trusts were able to report that they utilised strategies for ensuring AMS which included an antimicrobial stewardship committee or equivalent.

Since questions Q1.3 and Q1.4 were underfitting the model, further analyses of fit statistics were conducted. These were conducted in order to observe the behaviour of the items in domain 1 and also to investigate whether the removal of these items would improve the measurement of the underlying construct of 'antimicrobial management. Further analyses were conducted under the following conditions:

- removal of Q1.3 only *(see section 5.5.1.1)*
- removal of Q1.4 only *(see section 5.5.1.2)*
- removal of Q1.3 and Q1.4 *(see section 5.5.1.3)*

5.5.1.1 Removal of item Q1.3

On examination of the fit statistics, it was observed that the removal of Q1.3 caused the other items in domain 1 to be misfitting. Consequently, there was an observed increase in the INFIT MNSQ values obtained for items Q1.1, Q1.2, Q.1.4, Q1.5 and Q1.6 *(see table 5.7)*. Also, the INFIT MNSQ value for Q1.4 increased from INFIT MNSQ 1.63 to INFIT MNSQ 1.95. The assumption of unidimensionality states that an ideal INFIT MNSQ is equal to 1 *(see section 2.4.11.2.1)*. Therefore, since there was increase in the INFIT MNSQ for these items, this indicated that the removal of this item introduced noise into the domain because the INFIT MNSQ deviated from the ideal (INFIT MNSQ =1). Consequently, it was decided to retain Q1.3 in Domain1 for further analysis.

Table 5.7 - ITEM STATISTICS: Removal of item Q1.3: (DOMAIN 1) - ASAT v17

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
1.1	26	33	1.26	0.53	0.89	-0.30	0.88	-0.20
1.2	32	33	-1.90	1.13	1.03	0.30	0.20	-0.40
1.4	31	33	-0.91	0.87	**1.95**	1.40	1.82	1.00
1.5	50	31	2.77	0.50	0.93	-0.40	0.82	-1.00
1.6	30	31	-1.84	1.15	0.48	-0.60	0.09	-0.70
1.7	30	31	-1.84	1.15	0.48	-0.60	0.09	-0.70
1.8	21	33	2.46	0.47	1.01	0.20	0.91	-0.10
Mean	31.4	32.1	0.00	0.83	0.97	0.00	0.69	-0.20
S.D	8.3	1.0	1.95	0.30	0.45	0.70	0.58	0.50

Nb. Misfitting items in Table 5.7 have been highlighted in blue.

5.5.1.2 Removal of item Q 1.4

On analysis of the fit statistics, it was observed that the removal of Q1.4 also destabilised the model by producing an increased misfit of Q1.3 *(see table 5.8)*. This resulted in an increase INFIT MNSQ from 1.35 to 1.68 for Q1.3. However, it was observed that the removal of item Q1.4 resulted in an increased fit in the other items within this domain which was indicated by the reduction in the INFIT MNSQ values. This resulted in the mean INFIT MNSQ for domain 1 remaining unchanged. Therefore, Q1.4 was retained in domain 1 for further analysis *(see section 5.5.1.3)*.

Table 5.8 - ITEM STATISTICS (DOMAIN 1- ASAT v17): Removal of item Q1.4

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
1.1	26	33	1.27	0.53	0.90	-0.30	0.85	-0.20
1.2	32	33	-2.14	1.16	0.71	-0.20	0.11	-0.60
1.3	28	32	0.20	0.69	**1.68**	1.30	2.01	1.40
1.5	50	31	2.48	0.47	0.98	-0.10	0.88	-0.10
1.6	30	31	-2.14	1.16	0.71	-0.20	0.11	-0.60
1.7	30	31	-2.14	1.16	0.71	-0.20	0.11	-0.60
1.8	21	33	2.48	0.47	0.85	-1.10	0.76	-0.30
Mean	31.0	32.0	0.00	0.81	0.94	-0.10	0.69	-0.20
S.D	8.4	0.9	1.99	0.31	0.32	0.70	0.63	0.70

Nb. Misfitting items in Table 5.8 have been highlighted in blue.

The next stage of the analysis was to determine whether the removal of both Q1.3 and Q1.4 would improve the fit of the other items in domain 1.

5.5.1.3 Removal of item Q1.3 and item Q1.4

After the removal of items Q1.3 and Q1.4 from domain 1, it was observed that two sub-scales were generated, that is, Subset 1 and Subset 3 were produced *(see table 5.9)*. The removal of both these items clearly destabilised the model due to the

production of these two subscales, which indicated that the removal of these items caused multidimensionality to be exhibited. In other words, the removal of these items resulted in two separate, distinct subsets of domain 1.

Table 5.9 - ITEM STATISTICS: (DOMAIN 1-ASAT v17): Removal of items Q1.3 and Q1.4

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
1.1	26	33	2.20	0.58	0.99	0.10	0.88	0.20
1.2	32	33	-3.15	1.39	1.71	1.10	0.20	-0.40
1.5	50	31	3.62	0.51	0.97	-0.10	0.83	0.10
1.6	30	31	-3.15	1.39	0.44	-0.90	0.05	-0.80
1.7	30	31	-3.15	1.39	0.44	-0.90	0.05	-0.80
1.8	21	33	3.62	0.51	0.97	-1.10	0.83	0.10
Mean	31.5	32.0	0.00	0.96	0.92	-0.10	0.47	-0.30
S.D	9.0	1.0	3.19	0.43	0.43	0.70	0.37	0.40

Nb. Multidimensionality exhibited where Q1.1, Q1.5 and Q1.8 formed subset 1 (shaded in orange) and Q1.2, Q1.6 and Q1.7 formed subset 2 (not shaded)

Consequently, the removal of these items resulted in a domain that measured two or more constructs. The possibility of the existence of multidimensionality violates the assumption of unidimensionality therefore it was decided not to eliminate these two questions from the measure. Ideally, the measure should be unidimensional in order to measure a single underlying variable and hence fulfil the assumptions of Rasch modelling.[230] The item fit statistics demonstrated that there was a justification for retaining Q1.3 and Q1.4 in the domain for further analysis because the model was more stable with the inclusion of these items than their exclusion. Further analysis of domain 1 included Q1.3 and Q1.4 in overall analysis of ASAT v17.

The reasons for the observed misfit of item Q1.3 could be linked to respondents' inability to access the data required to answer questions and subsequently format responses (*see section 3.7 and section 3.9)*. For Q1.4, which asks *'Does the Trust have an antimicrobial committee or equivalent accountable to the Infection Control (IC) or Drugs and Therapeutics Committee (DTC)?'*, a portion of respondents indicated that they did a have antimicrobial stewardship committee in their hospitals. However, some respondents found the concept of antimicrobial stewardship committee difficult to interpret because they did not have a *'formalised'* committee within their hospitals. They reported that they considered meetings with the clinical microbiologists as equivalent to their *'antimicrobial committee'*. These meetings were *ad hoc* and unplanned but they would discuss antimicrobial-related issues. This item

(Q1.4) could be misfitting due to the respondents' inability to comprehend the meaning of the phrase *'antimicrobial committee or equivalent'* which subsequently affected the responses given to Q1.4. Therefore, Q1.3 and Q1.4 may need to further revision in order to improve the interpretation by respondents.

5.5.2 DOMAIN 2 (Operational delivery of the antimicrobial stewardship strategy)

Rasch modelling was unable to provide estimates for perfectly scored items therefore, in instances where all NHS trusts provided perfect scores to some items in domain 2. Consequently, these items (Q2.1, Q2.7, Q2.9 and Q2.13) were dropped from the analysis by WINSTEPS *(see table 5.10)* because these items lacked the ability to discriminate between NHS trusts and their difficulty cannot be estimated by the PCM. However, these items were retained in the item pool of domain 2 for further analysis, that is, to determine their behaviour within the entire item pool of ASAT v17 *(see section (5.5.9).*These questions were related to the NHS trusts' antimicrobial policies and treatment guidelines and these results indicated that NHS trusts used these documents as part of their ASP implementation strategy.

The mean of the NHS trusts (M) was located higher than the item mean for domain 2 and the NHS trusts were normally distributed with a few outliers *(see figure 5.2)*. This indicated that NHS trusts were generally able to endorse the questions in domain 2.

NHS trusts scored highly for this domain which indicated that these organisations utilised antimicrobial policies, guidelines and formularies as part of their implementation strategy for ASPs. Item Q2.21 which asked how frequently antimicrobial guidelines were reviewed was the most difficult item for NHS trusts to report compliance *(see figure 5.2)*.

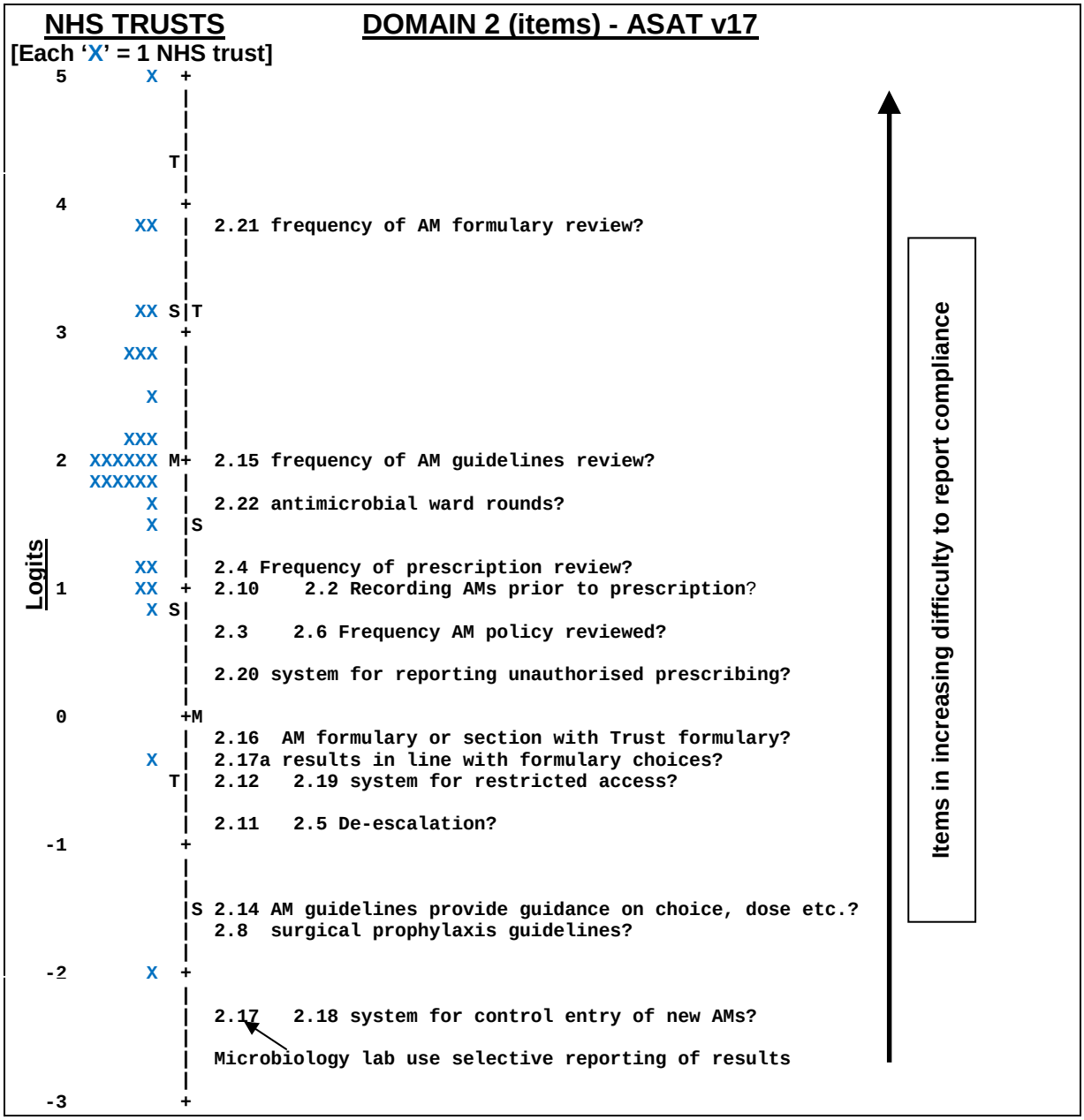

Figure 5.2 - Respondents/items map (Domain 2) *Nb.*
Q2.1, Q2.7, 2.9 and 2.13 were dropped from the analysis by WINSTEPS.
Abbreviations used: antimicrobial (AM)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust

Items Q2.17 and Q2.18 were the easiest items in this domain to report compliance, where item Q2.17 examined whether microbiology laboratories used selective of results and item Q2.18 examined whether there was a system for control of entry of new antimicrobials. On examination of the fit statistics for domain 2, it was observed that Q2.17 (INFIT MNSQ 1.63) was the only item underfitting domain 2 *(see table*

5.10). Item Q2.18 (INFIT MNSQ 0.39) appeared to be overfitting the model hence providing redundant information. It was therefore decided to rerun the analysis of fit statistics with the removal of items Q2.17 and Q2.18. All other items within this domain appeared to be measuring the unitary concept of the 'Operational delivery of antimicrobial stewardship strategies in NHS trusts, hence fulfilling the assumption of unidimensionality. In other words, these items appear to working well together to define 'Operational Delivery of the Antimicrobial Strategy'.

Table 5.10 - ITEM STATISTICS (DOMAIN 2) - ASAT v17

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
2.2	74	33	0.22	0.24	0.98	0.00	1.01	0.20
2.3	76	33	0.52	0.28	0.66	-1.20	0.55	-1.40
2.4	45	33	1.08	0.28	1.26	1.10	1.13	0.40
2.5	30	33	-1.00	0.70	1.02	0.20	0.96	0.30
2.6	43	33	0.60	0.36	0.80	-0.90	0.76	-1.00
2.8	31	32	-1.88	1.04	1.01	0.30	0.45	0.00
2.10	23	33	0.88	0.42	1.07	0.40	1.13	0.50
2.11	30	33	-1.00	0.70	1.02	0.20	4.02	2.10
2.12	29	32	-0.63	0.64	1.12	0.40	1.75	1.00
2.14	121	33	-0.59	0.39	1.09	0.40	0.99	0.10
2.15	49	33	1.99	0.39	0.79	-1.70	0.70	-0.80
2.16	28	33	-0.24	0.55	1.24	0.70	1.31	0.60
2.17	31	32	-2.55	1.16	**1.63**	0.90	1.27	0.70
2.17a	28	32	-0.53	0.61	1.11	0.40	0.92	0.20
2.18	32	33	-2.57	1.16	**0.39**	-0.60	0.05	-0.90
2.19	29	33	-0.58	0.61	0.69	-0.60	0.39	-0.70
2.20	23	33	0.88	0.42	0.92	-0.40	1.17	0.50
2.21	47	31	3.87	0.36	1.00	0.10	0.97	-0.10
2.22	39	33	1.52	0.26	1.15	0.80	1.22	0.70
Mean	42.5	32.7	0.00	0.56	1.00	0.00	1.09	0.10
S.D	23.6	0.6	1.53	0.28	0.26	0.70	0.79	0.80

Nb. Misfitting items in Table 5.11 have been highlighted in blue. Items Q2.1, Q2.7, Q2.9 and 2.13 have been dropped from the analysis by WINSTEPS

Item Q2.17 which asked '*Does the microbiology laboratory use selective reporting of results?'* was underfitting the model. This could be due to respondents indicating that their hospitals' clinical microbiology laboratories generally reported results in line with formulary choices. However, there were numerous instances where the laboratories would report off-formulary antimicrobials as well. Another reason for Q2.17 not fitting could be that this question was potentially measuring an external variable which is not directly related to the content of domain 2. This domain evaluated the policies, guidelines and formularies which NHS trusts utilised in their ASPs. Therefore, a question which asked about the activity related to clinical microbiology laboratories

may not fit this section and could be included within Domain 7 in future iterations of the ASAT. Item Q2.18 asked *'Is there a system for control of entry of new antimicrobials?',* was slightly overfitting the model. The INFIT MNSQ value indicated that this item could be a redundant item which did not contribute to the measure (domain 2). Most respondents indicated that the term *'system'* was difficult to interpret *(see section 3.6.1.2)* which could negatively affect the question sensitivity of Q2.18.

5.5.2.1 Removal of item Q2.17

The analysis was conducted again after the removal of item Q2.17. The removal of Q2.17 had a relatively small (negligible) impact on the fit indices for domain 2 *(see table 5.11)*.

Table 5.11 - ITEM STATISTICS (DOMAIN 2 - ASATv17): Removal of items Q2.17

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
2.2	74	33	0.23	0.24	0.99	0.00	1.03	0.20
2.3	76	33	0.53	0.28	0.69	-1.10	0.57	-1.40
2.4	45	33	1.08	0.27	1.20	0.90	1.08	0.30
2.5	30	33	-1.00	0.70	1.02	0.20	0.99	0.30
2.6	43	33	0.59	0.35	0.83	-0.80	0.79	-0.90
2.8	31	32	-1.87	1.04	1.01	0.30	0.45	0.00
2.10	23	33	0.87	0.42	1.06	0.40	1.08	0.30
2.11	30	33	-1.00	0.70	1.01	0.20	3.70	2.00
2.12	29	32	-0.62	0.63	1.11	0.40	1.67	0.90
2.14	121	33	-0.58	0.39	1.08	0.40	1.00	0.10
2.15	49	33	1.95	0.38	0.82	-1.60	0.73	-0.70
2.16	28	33	-0.24	0.55	1.21	0.60	1.16	0.50
2.17a	28	32	-0.54	0.61	1.09	0.30	0.92	0.20
2.18	32	33	-2.56	1.16	**0.39**	-0.60	0.05	-0.90
2.19	29	33	-0.57	0.61	0.71	-0.60	0.41	-0.70
2.20	23	33	0.87	0.42	0.93	-0.30	1.16	0.50
2.21	47	31	3.80	0.36	1.04	0.20	1.02	0.10
2.22	56	33	1.61	0.18	1.18	0.90	1.20	0.50
Mean	43.4	32.7	0.00	0.55	1.00	0.00	1.07	0.10
S.D	23.8	0.00	1.52	0.25	0.25	0.70	0.71	0.80

Nb. Misfitting items in Table 5.12 have been highlighted in blue. Items Q2.1, Q2.7, Q2.9 and 2.13 have been dropped from the analysis by WINSTEPS

5.5.2.2 Removal of item Q2.18

Item Q2.18 (INFIT MNSQ 0.39) was overfitting the model and it was removed from the pool of items of domain 2 and then the dataset was reanalysed. The removal of item Q2.18 from the analysis resulted in a very small change (negligible) in the fit indices where most infit indices remained unchanged *(see table 5.12).*

Table 5.12 - ITEM STATISTICS (DOMAIN 2 - ASATv17): Removal of items Q2.18

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
2.2	74	33	0.06	0.24	1.11	0.60	1.16	0.60
2.3	76	33	0.34	0.28	0.78	-0.70	0.69	-1.00
2.4	45	33	0.92	0.28	1.27	1.20	1.19	0.60
2.5	30	33	-1.18	0.70	1.06	0.30	1.24	0.60
2.6	43	33	0.43	0.36	0.95	-0.10	0.92	-0.30
2.8	31	32	-2.06	1.04	1.01	0.30	0.44	0.00
2.10	23	33	0.72	0.42	1.09	0.50	1.15	0.50
2.11	30	33	-1.18	0.70	1.02	0.20	4.35	2.40
2.12	29	32	-0.80	0.64	1.09	0.30	1.27	0.60
2.14	121	33	-0.76	0.39	1.14	0.60	1.24	0.80
2.15	49	33	1.82	0.39	0.93	-0.06	0.85	-0.30
2.16	28	33	-0.41	0.55	1.22	0.70	1.15	0.50
2.17	31	32	-2.54	1.16	1.62	0.90	1.25	0.60
2.17a	28	32	-0.72	0.62	1.10	0.40	0.99	0.20
2.19	29	33	-0.75	0.61	0.71	-0.60	0.43	-0.80
2.20	23	33	0.72	0.42	0.97	-0.10	1.30	0.90
2.21	39	33	1.36	0.25	0.71	-1.60	0.63	-1.10
2.22	56	33	1.47	0.18	0.79	-1.00	0.66	-0.70
Mean	44.4	32.8	0.00	0.48	1.00	0.00	1.16	0.20
S.D	24.8	0.00	1.06	0.22	0.16	0.70	0.85	0.80

As previously discussed, overfitting items are overly predictable and do not distort the measure significantly. Therefore, the removal of item Q2.18 did not have a significant effect on the fit indices for domain 2.

5.5.2.3 Removal of item Q2.17 and Q2.18

The infit statistics showed that there was a slight improved item fit after the removal of items Q2.17a and Q2.18 where the remaining items had an INFIT MNSQ range between 0.71 and 1.27 *(see table 5.13)*. However, item Q2.17b was dependent on the response to Q2.17a, in other words, these items exhibited item dependency *(see section 2.4.11)* which violated one of the assumptions of Rasch modelling. Therefore, the removal of Q2.17a would render item Q2.17b redundant.

Table 5.13- ITEM STATISTICS: (DOMAIN 2 - ASATv17) Removal of items Q2.17a and Q2.18

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
2.2	74	33	0.06	0.24	1.11	0.60	1.16	0.60
2.3	76	33	0.34	0.28	0.78	-0.70	0.69	-1.00
2.4	45	33	0.92	0.28	1.27	1.20	1.19	0.60
2.5	30	33	-1.18	0.70	1.06	0.30	1.24	0.60
2.6	43	33	0.43	0.36	0.95	-0.10	0.92	-0.30
2.8	31	32	-2.06	1.04	1.01	0.30	0.44	0.00
2.10	23	33	0.72	0.42	1.09	0.50	1.15	0.50
2.11	30	33	-1.18	0.70	1.02	0.20	4.35	2.40
2.12	29	32	-0.80	0.64	1.09	0.30	1.27	0.60
2.14	121	33	-0.76	0.39	1.14	0.60	1.24	0.80
2.15	49	33	1.82	0.39	0.93	-0.06	0.85	-0.30
2.16	28	33	-0.41	0.55	1.22	0.70	1.15	0.50
2.17a	28	32	-0.72	0.62	1.10	0.40	0.99	0.20
2.19	29	33	-0.75	0.61	0.71	-0.60	0.43	-0.80
2.20	23	33	0.72	0.42	0.97	-0.10	1.30	0.90
2.21	39	33	1.36	0.25	0.71	-1.60	0.63	-1.10
2.22	56	33	1.47	0.18	0.79	-1.00	0.66	-0.70
Mean	44.4	32.8	0.00	0.48	1.00	0.00	1.16	0.20
S.D	24.8	0.00	1.06	0.22	0.16	0.70	0.85	0.80

On examination of the item/respondent map for domain 2 after the removal of items Q2.17 and Q2.18, it was observed that the distribution of the logit positions of NHS trusts was positively skewed *(see figure 5.3)*.

Consequently, it was decided to retain item Q2.17 in domain 2. The reasons for the observed misfit of item Q2.17 could be that this question was potentially measuring an external variable which was not directly related to Domain 2. This domain evaluated the policies, guidelines and formularies which NHS trusts utilised in their ASPs. Therefore, a question which asked about the activity related to clinical microbiology laboratories may not fit this section and maybe included within Domain 7. Item Q2.18 was retained in the pool of items for further analysis which would result in the next iteration of the ASAT.

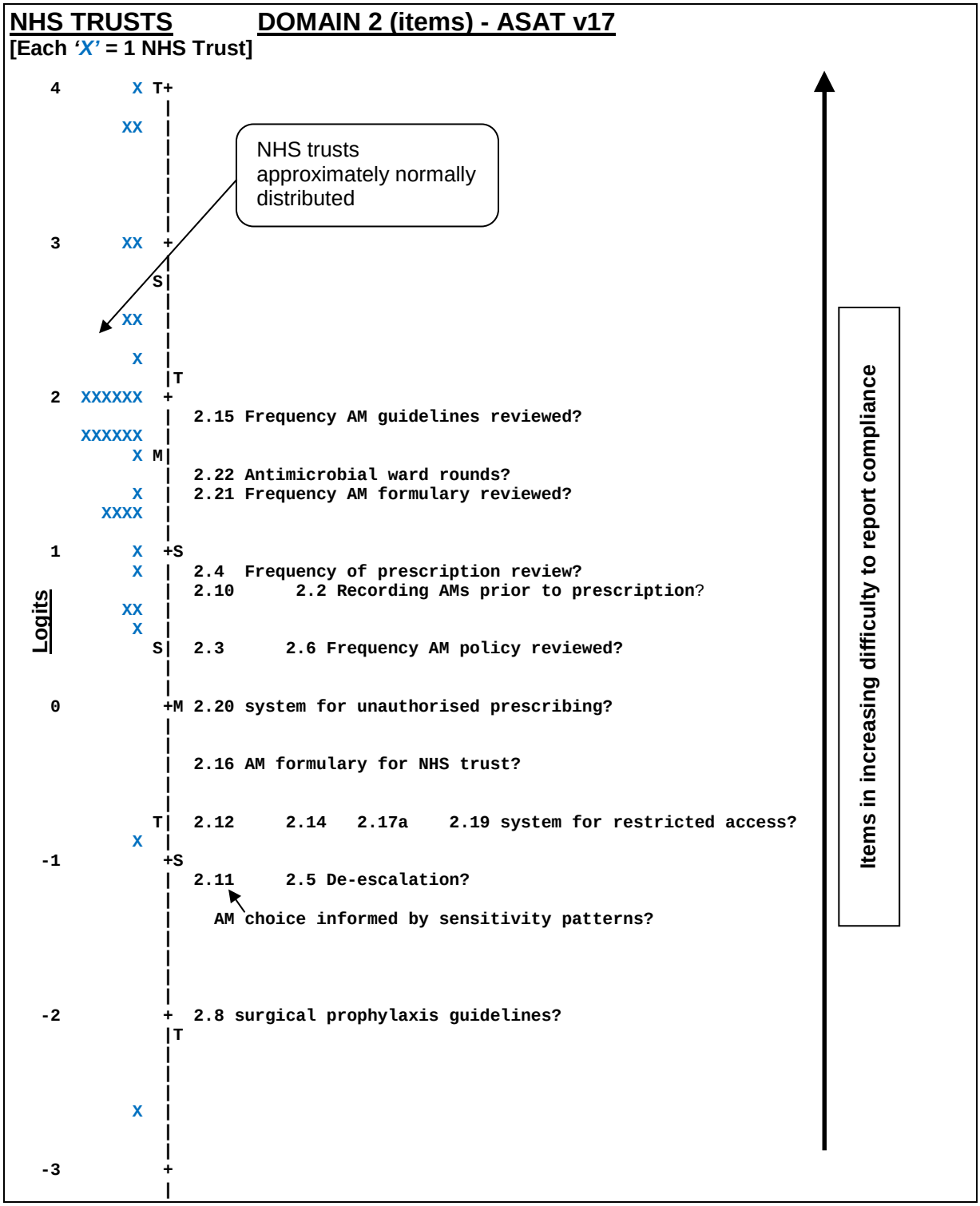

Figure 5.3 - Respondents/items map (Domain 2)

Nb. Q2.1, Q2.7, 2.9 and 2.13 were dropped from the analysis. Abbreviations used: antimicrobial (AM)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust

5.5.3 DOMAIN 3 (Risk assessment for antimicrobial chemotherapy)

All items in domain 3 had INFIT MNSQ statistics between 0.79 and 1.23 so therefore these were fitting the model *(see table 5.14).* Consequently, fulfilling the assumptions of unidimensionality where these items appear to be measuring the unitary concept of risk assessment for antimicrobial chemotherapy.

Table 5.14 - ITEM STATISTICS: (DOMAIN 3 - ASATv17)

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
3.1	31	33	-0.85	0.81	1.05	0.30	0.86	0.00
3.2	27	32	0.58	0.64	0.94	-0.20	0.93	-0.20
3.3	31	33	-0.85	0.81	0.79	-0.30	0.62	-0.50
3.4	30	33	-0.29	0.70	1.02	0.20	0.87	-0.20
3.5	26	33	1.40	0.66	1.26	1.10	1.23	0.80
Mean	29.0	32.8	0.00	0.72	1.01	0.20	0.90	0.00
S.D	2.1	0.40	0.88	0.70	0.15	0.50	0.19	0.40

However, ceiling effects were observed on examination of the item/respondent map for domain 3 *(see figure 5.4)* where most respondents were located at the top of the operational range for this domain. Although, these items fulfilled the assumption of unidimensionality, they did not fulfil the assumption of item discrimination because there were unable to discriminate between NHS trusts. Also, the resulting skewed distribution was observed due to the lack of variation of responses from NHS trusts. These ceiling effects were produced because most NHS trusts reported that they utilised implementation strategies for risk assessment for antimicrobial chemotherapy which were contained in ASAT v17. In other words, NHS trusts were compliant with the strategies contained in domain and so therefore responded positively to these items. This result was expected because most respondents in previous studies indicated that their NHS trusts were compliant to this domain. In order to improve item discrimination within this domain, additional items may be required to conduct a rigorous examination of the processes NHS trusts use to implement risk assessment for antimicrobial chemotherapy.

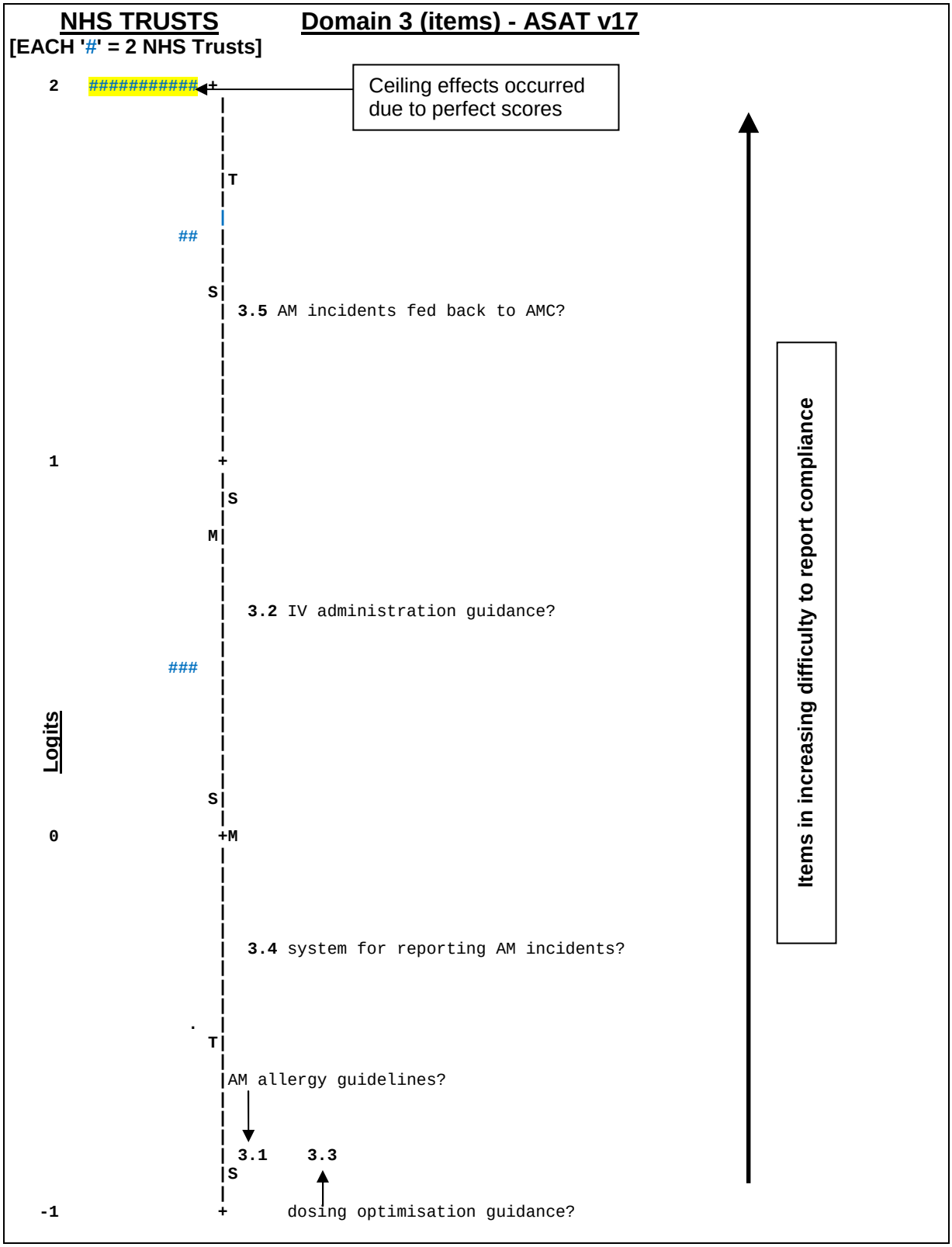

Figure 5.4 - Respondents/items map (Domain 3)

Nb. Abbreviations antimicrobial (AM) and antimicrobial committee (AMC)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust
#	Two NHS trusts

Item Q3.5 appeared to have the greatest ability to discriminate between NHS trusts. Items Q3.1 and Q3.3 possessed the lack the ability to discriminate in this domain. The NHS trusts with homogeneous (perfect) scores were identified from examining the respondent statistics and it was observed that there were 22 out of 33 NHS trusts achieving the maximum measure for this domain *(table 5.15)*.

Table 5.15 - NHS Trust STATISTICS: (DOMAIN 3 - ASAT v17)

NHS trust	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
1	5	5	3.06	1.90	**MAXIMUM MEASURE**			
2	5	5	3.06	1.90	**MAXIMUM MEASURE**			
3	5	5	3.06	1.90				
4	3	5	0.46	1.00	1.12	0.40	1.19	0.50
5	5	5	3.06	1.90	**MAXIMUM MEASURE**			
6	5	5	3.06	1.90	**MAXIMUM MEASURE**			
7	5	5	3.06	1.90	**MAXIMUM MEASURE**			
8	3	5	0.46	1.00	0.49	-1.40	0.46	-1.30
9	5	5	3.06	1.90	**MAXIMUM MEASURE**			
10	4	5	1.60	1.19	0.57	-0.60	0.38	-0.50
11	4	5	1.60	1.19	1.00	0.40	0.78	0.10
12	4	5	1.60	1.19	0.57	-0.60	0.38	-0.50
13	3	5	0.46	1.00	1.28	0.80	1.22	0.60
14	5	5	3.06	1.90	**MAXIMUM MEASURE**			
15	5	5	3.06	1.90	**MAXIMUM MEASURE**			
16	5	5	3.06	1.90	**MAXIMUM MEASURE**			
17	5	5	3.06	1.90	**MAXIMUM MEASURE**			
18	5	5	3.06	1.90	**MAXIMUM MEASURE**			
19	5	5	3.06	1.90	**MAXIMUM MEASURE**			
20	5	5	3.06	1.90	**MAXIMUM MEASURE**			
21	5	5	1.60	1.90	**MAXIMUM MEASURE**			
22	4	5	0.46	1.19	0.57	-0.60	0.38	-0.50
23	3	5	3.06	1.00	1.50	1.20	1.58	1.20
24	5	5	-0.50	1.90				
25	2	5	0.46	0.98	0.87	-0.30	0.77	-0.30
26	3	5	2.73	1.00	1.92	1.90	1.96	1.80
27	4	4	3.06	1.95	**MAXIMUM MEASURE**			
28	5	5	3.06	1.90	**MAXIMUM MEASURE**			
29	5	5	3.06	1.90	**MAXIMUM MEASURE**			
30	5	5	3.06	1.90	**MAXIMUM MEASURE**			
31	5	5	3.06	1.90	**MAXIMUM MEASURE**			
32	3	5	0.46	1.00	0.91	-0.10	0.83	-0.20
33	5	5	3.06	1.90	**MAXIMUM MEASURE**			
Mean	4.40	5.00	2.29	1.62	0.99	0.10	0.90	0.10
S.D	0.90	200	1.13	0.40	0.43	0.90	0.50	0.80

There was no item deletion performed because the items in Domain 3 exhibited good fit however it should be noted that this domain does not discriminate between high and low performing NHS trusts.

5.5.4 DOMAIN 4 (Clinical Governance and Audit)

On examination of the fit statistics for Domain 4, it was observed that Q4.1 (INFIT MNSQ 0.59) was slightly overfitting the model which indicated that item Q4.1 could be a redundant item in Domain 4. Also, it was observed that item Q4.8 (INFIT MNSQ 1.45) was underfitting the model and therefore introducing *'noise'* into the domain *(see table 5.16)*. All other items within this domain appear to have good fit and thus appear to measure the unitary concept of the implementation strategy of clinical governance and audit in ASPs.

Table 5.16: ITEM STATISTICS: (DOMAIN 4 - ASAT v17)

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
4.1	30	33	-2.41	0.68	**0.59**	-0.80	0.27	-0.60
4.2	28	33	-1.67	0.55	0.79	-0.55	0.79	-0.50
4.3	12	33	1.45	0.44	0.72	-1.40	0.58	-1.00
4.4	26	32	-1.34	0.52	1.07	0.30	0.88	0.00
4.5	18	33	0.39	0.41	0.85	-0.90	0.79	0.70
4.6	13	33	1.26	0.43	1.16	0.90	1.83	1.80
4.7	11	33	1.65	0.45	0.74	-1.20	0.56	-0.90
4.8	40	33	0.11	0.27	**1.45**	1.80	2.59	2.70
4.9	14	33	1.08	0.42	0.95	-0.20	0.91	-0.10
4.10	20	32	-0.11	0.43	1.03	0.30	1.02	0.20
4.11	22	32	-0.48	0.44	1.10	0.60	1.17	0.50
4.12	19	32	0.07	0.42	1.10	0.60	1.07	0.30
Mean	21.1	32.7	0.00	0.45	0.96	-0.10	1.03	0.20
S.D	8.3	0.50	1.24	0.09	0.23	0.90	0.60	1.10

Nb. Overfitting and underfitting items in Table 5.17 have been highlighted in blue.

However, on examination of the item/respondent maps it was demonstrated that there was a binomial distribution between items and NHS trusts *(see figure 5.5)*. This was an indication that this domain was a good, well-constructed measure due to its ability to discriminate between NHS trusts. The item difficulty mean and the respondent ability mean were located close together which indicated that there was good item targeting in domain 4. Item Q4.7 which asked if NHS trusts audited their therapeutic drug monitoring guidelines was the most difficult item for NHS trusts to respond positively to. Item Q4.1 which asked NHS trusts if they had an antimicrobial audit strategy was the easiest item in this domain and as discussed previously was overfitting the model.

Item Q4.1 which asked *'Is there an antimicrobial audit strategy?'* appeared to be overfitting the model. This overfit indicated that this question was redundant and did not contribute significantly to the measure. This may be due to some respondents indicating that they engaged on audit activities although there were no formalised

audit strategy or programme within their Trusts. Examples of these antimicrobial-related audits included point prevalence audits/studies however the frequency of these audits would be triggered by numerous factors such as infection outbreaks. This interpretation reinforces the need for a glossary which clearly defines the phrase *'audit strategy'*.

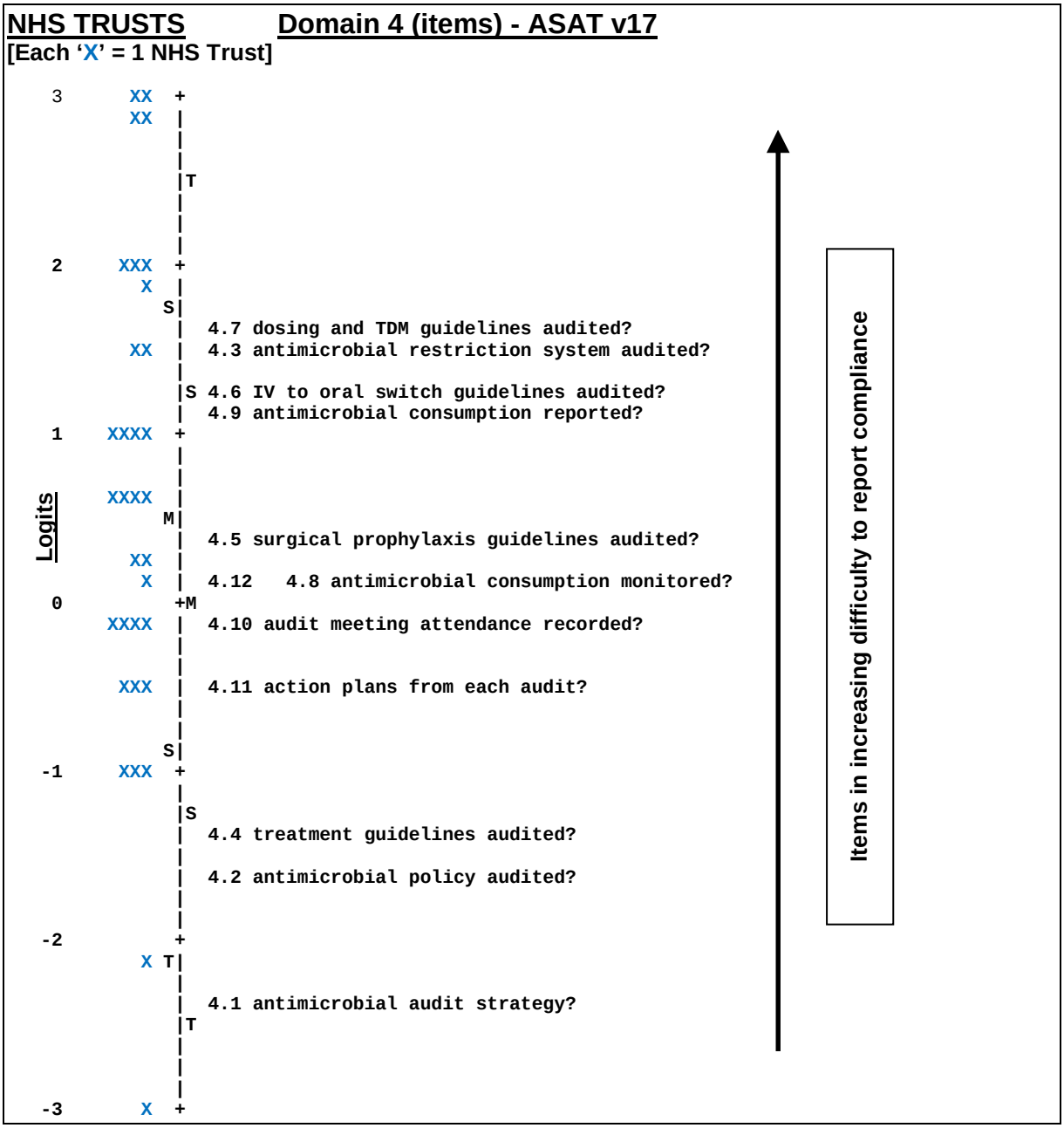

Figure 5.5 - Respondents/items map (Domain 4)
Nb. Abbreviations used; therapeutic drug monitoring (TDM)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust
#	Two NHS trusts

Item Q4.8 which asked *'Is antimicrobial consumption monitored e.g. in DDDs per activity?* was underfitting the model. Respondents reported that there were difficulties in measuring antimicrobial consumption in daily defined doses (DDDs) *(see section 3.10.5)* and there are as follows:

- DDDs were measured but not for every antimicrobial prescribed across the Trust because it would be a very labour intensive process
- DDDs were impossible to quantify for usage in paediatrics primarily due to the variable age/weight ratios observed in paediatric populations

Since item Q4.1 and Q4.8 were misfitting the model it was necessary to investigate the effect of removing these items as stipulated in the fit analysis guidelines.[274] Consequently, it was decided to examine the fit statistics obtained when item Q4.1 and item Q4.8 were separately removed from the analysis *(see section 5.5.4.1)*.

5.5.4.1 Removal of item Q4.1

The removal of item Q4.1 resulted in the mean INFIT MNSQ to increase from 0.96 to 0.98 in other words, the overall INFIT MNSQ was closer to 1 (ideal INFIT MNSQ). This indicated that there was an improved item fit within domain 4 as a result of the removal of this item (*see table 5.17)*. Item Q4.8 (INFIT MNSQ 1.45) remained underfitting the model and the analysis was conducted after the removal of this item *(see section 5.5.4.2)*.

Table 5.17 - ITEM STATISTICS (DOMAIN 4): Removal of item Q4.1

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
4.2	28	33	-1.84	0.54	0.78	-0.60	0.62	-0.40
4.3	12	33	1.21	0.44	0.72	-1.50	0.59	-1.20
4.4	26	32	-1.53	0.51	1.03	0.20	0.86	0.00
4.5	18	33	0.16	0.41	0.85	-0.90	0.80	-0.70
4.6	13	33	1.03	0.43	1.15	0.80	1.49	1.40
4.7	11	33	1.41	0.45	0.74	-1.20	0.57	-1.10
4.8	40	33	-0.12	0.27	**1.45**	1.80	2.62	2.90
4.9	14	33	0.85	0.42	0.95	-0.20	0.93	-0.10
4.10	20	32	-0.33	0.42	1.00	0.10	1.00	0.10
4.11	22	32	-0.69	0.44	1.04	0.30	0.98	0.10
4.12	19	32	-0.15	0.42	1.06	0.40	1.05	0.30
Mean	20.3	32.6	0.00	0.46	0.98	-0.10	1.04	0.10
S.D	8.2	0.50	1.03	0.06	0.20	0.90	0.56	1.10

Nb. Underfitting items in Table 5.17 have been highlighted in blue.

5.5.4.2 Removal of item Q4.8

Item Q4.8 was removed from the analysis and the item fit statistics were re-examined *(see table 5.18)*. The removal of item Q4.8 slightly improved the infit of five out of eleven items of Domain 4 for example the INFIT MNSQ for Q4.5 decreased to 0.97*(see table 5.18)*. The overall mean INFIT MNSQ remained unchanged for domain 4.

Table 5.18 - ITEM STATISTICS (DOMAIN 4): Removal of item Q4.8

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
4.1	30	33	-2.50	0.67	0.67	-0.70	0.36	-0.60
4.2	28	33	-1.77	0.55	0.77	-0.60	0.61	-0.50
4.3	12	33	1.60	0.48	0.89	-0.40	0.76	-0.30
4.4	26	32	-1.45	0.52	0.97	0.00	0.87	-0.10
4.5	18	33	0.39	0.43	0.82	-1.00	0.77	-0.70
4.6	13	33	1.37	0.47	1.37	1.60	2.20	2.00
4.7	11	33	1.84	0.50	0.88	-0.40	0.63	-0.50
4.9	14	33	1.16	0.45	1.09	0.50	1.48	1.10
4.10	20	32	-0.15	0.44	1.08	0.50	1.21	0.50
4.11	22	32	-0.54	0.45	0.95	-0.20	1.08	0.40
4.12	19	32	0.05	0.44	1.10	0.60	1.09	0.40
Mean	19.4	32.6	0.00	0.49	0.96	0.00	1.00	0.20
S.D	6.3	0.50	1.39	0.07	0.18	0.70	0.48	1.80

The item-person map produced for Domain 4 indicated that there was a skewed normal distribution between NHS trusts and items but there was a ceiling effect generated resulting from the removal of item Q4.8. The observed ceiling effect was due to 5/33 NHS trusts obtaining the maximum score for Domain 4 *(see figure 5.6).* This indicated that these NHS trusts were able to report that they utilised all the strategies for clinical audit/governance as described by ASAT v17. The removal of this item appeared to only slightly diminish the ability of domain 4 to discriminate between NHS trusts due to the perfect scores obtained by 5/33 NHS trusts.

It was decided to retain item Q4.1 and item Q4.8 within domain 4 because the removal of these items negatively impacted on this domain's ability to discriminate between NHS trusts.

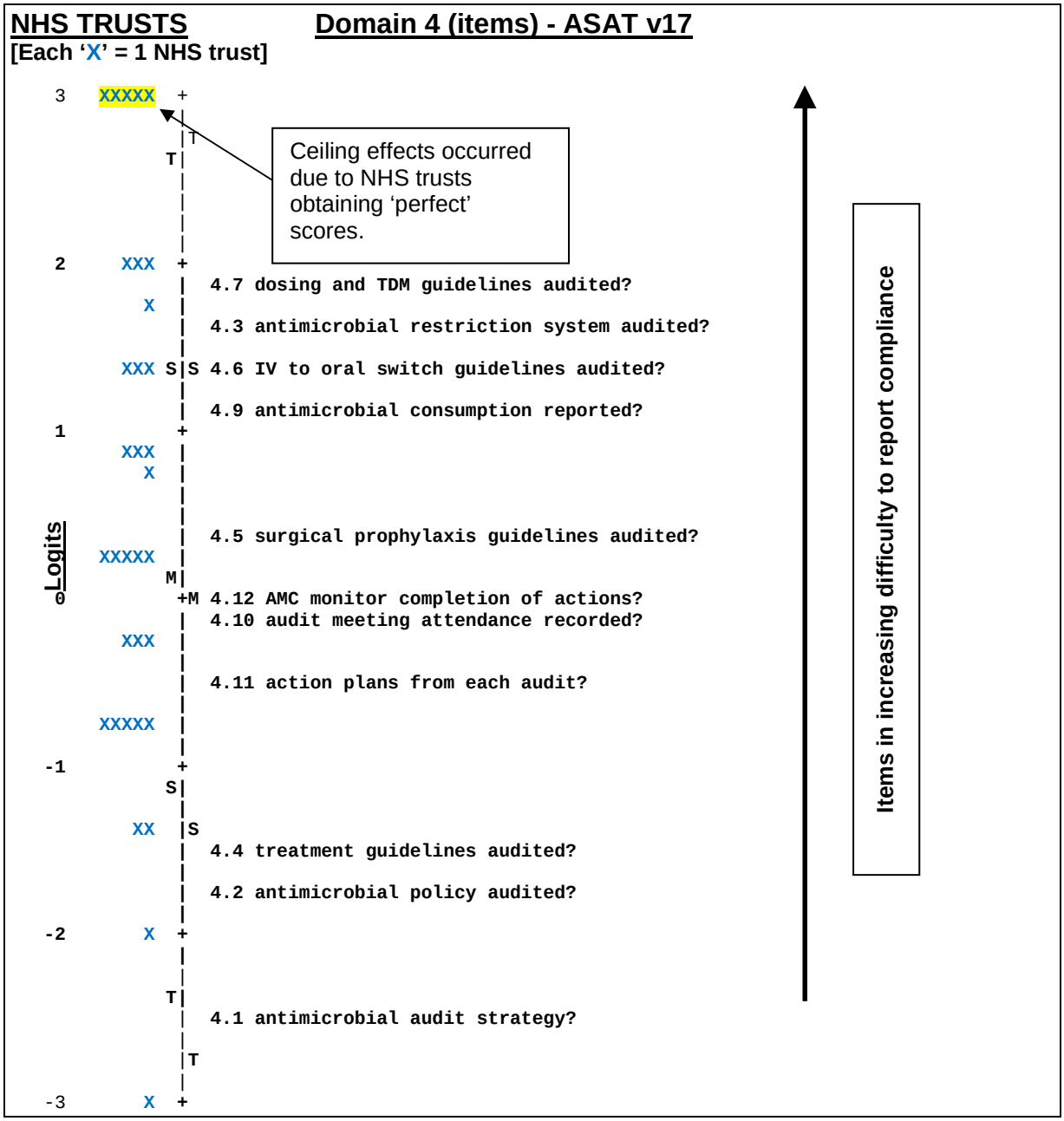

Figure 5.6 - Respondents/items map (Domain 4) - removal of Q4.8 (ceiling effect highlighted in yellow)

Nb. Abbreviations used: therapeutic drug monitoring (TDM) and antimicrobial committee (AMC)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust
#	Two NHS trusts

It was decided to retain item Q4.1 and item Q4.8 within domain 4 because the removal of these items caused instability in the model and negatively impacted on this domain's ability to discriminate between NHS trusts.

5.5.5 DOMAIN 5 (Education and Training)

It was observed that items Q5.9 (INFIT MNSQ 1.70) and Q5.10a (INFIT MNSQ 1.69) were both underfitting the model on examination of the fit statistics for Domain 5. In other words, the infit values for these items indicated that they may not be useful for measurement of education and training implementation strategies in NHS trusts. All other items within domain 5 demonstrated good fit *(see table 5.19)* with INFIT MNSQ values which ranged from 0.84 to 1.23. These items were within the range of INFIT MNSQ of 0.7 to 1.3 so therefore they appear to fulfil the assumption of unidimensionality by measuring the unitary concept of education and training strategies in NHS trusts for implementing hospital-based ASPs.

Table 5.19 - ITEM STATISTICS: DOMAIN 5 - ASAT v17

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
5.1	19	33	-0.87	0.38	0.96	-0.30	0.91	0.30
5.2	31	33	-3.74	0.79	0.76	-0.20	0.54	-0.20
5.3	29	33	-2.85	0.58	0.97	0.10	1.20	0.50
5.4	5	33	1.47	0.52	0.96	0.00	0.79	-0.10
5.5	12	33	0.14	0.39	0.94	-0.40	0.84	-0.50
5.6	9	33	0.62	0.42	0.96	-0.10	0.79	-0.40
5.7	15	33	-0.30	0.38	0.96	-0.30	1.79	2.80
5.8	4	33	1.76	0.57	0.84	-0.30	0.58	-0.40
5.9	10	33	1.46	0.36	**1.70**	1.50	1.25	0.60
5.10	77	33	-1.40	0.21	1.17	0.60	0.86	0.00
5.10a	39	33	-0.16	0.18	**1.69**	3.00	1.64	1.40
5.11	42	31	-0.35	0.17	0.96	-0.10	0.99	0.30
5.11a	16	31	0.61	0.23	1.04	0.20	0.74	0.00
5.12	29	31	-0.03	0.17	0.98	0.00	0.61	0.00
5.12a	11	31	0.74	0.27	0.87	-0.10	0.46	0.00
5.13	22	32	0.26	0.19	0.75	-0.90	0.43	-0.40
5.13a	13	32	0.72	0.25	0.77	-0.40	0.91	0.30
5.14	21	32	0.30	0.20	1.01	0.10	1.67	1.00
5.14a	14	32	0.67	0.25	0.82	-0.30	0.45	-0.50
5.15	58	33	-0.73	0.17	1.11	0.50	0.89	0.00
5.15a	48	33	-0.44	0.16	1.03	0.20	0.81	0.00
5.16	3	33	2.13	0.64	1.23	0.60	1.01	0.30
Mean	24.0	32.5	0.00	0.34	1.02	0.20	0.92	0.20
S.D	18.5	0.80	1.35	0.18	0.24	0.80	0.38	0.70

Nb. Misfitting items in Table 5.19 have been highlighted in blue.

Both items Q5.9 and Q5.10a appeared to be underfitting the model. Item Q5.9, which asked *'Is an annual update in optimal prescribing available for staff who administer antimicrobials?,* respondents indicated that they did not think that it was necessary for staff who administer antimicrobials such as nurses to receive in

optimal prescribing. Respondents also indicated that training in optimal prescribing was not available for nurses from the pharmacy department.

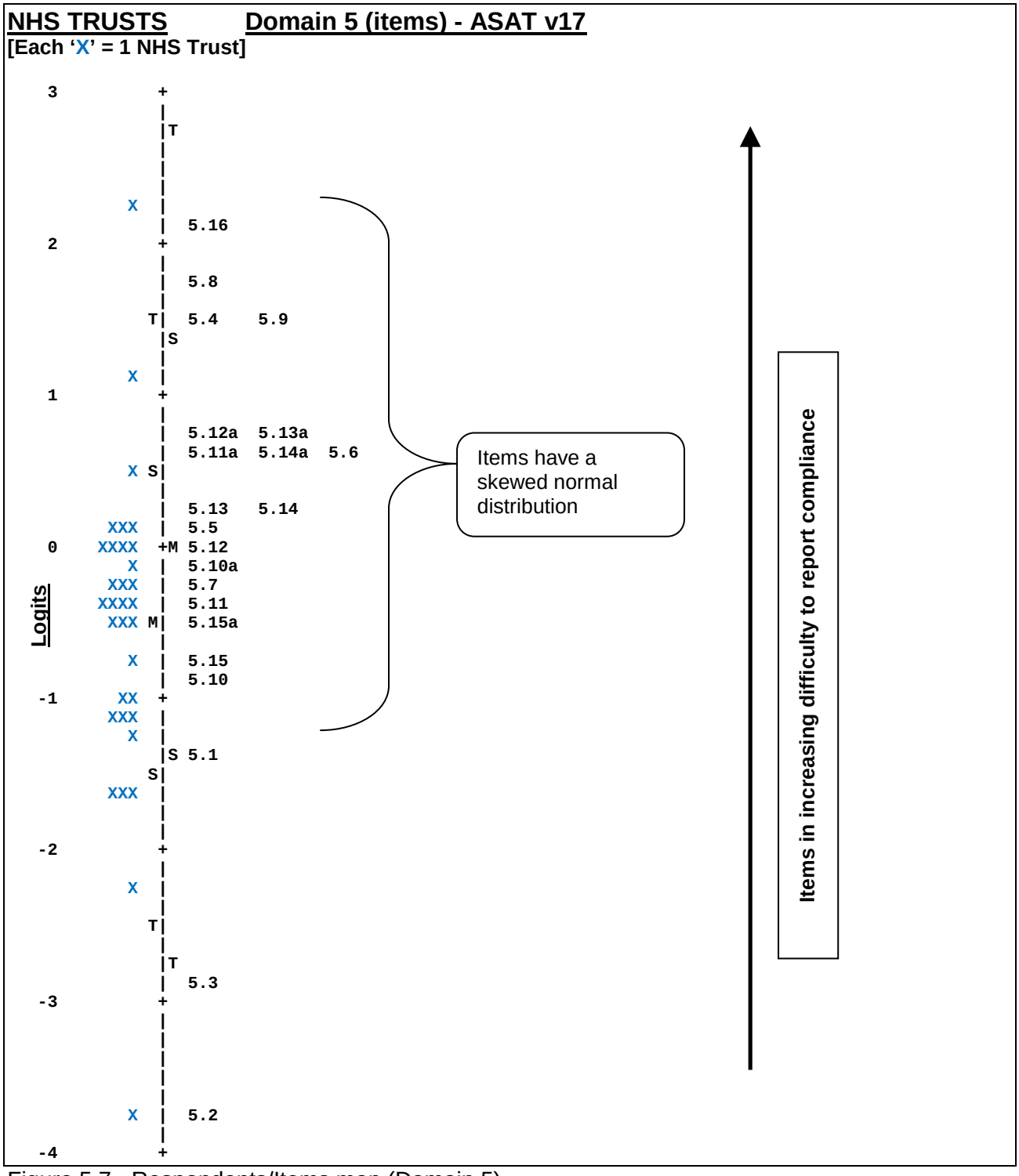

Figure 5.7 - Respondents/Items map (Domain 5)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust
#	Two NHS trusts

However, they indicated that nurses may receive this training as part of the Trusts infection prevention and control mandatory training but the pharmacists were unaware of the content of these training packages *(see section 3.6.1.2)*. Item Q5.10a which asks *'what proportion of Foundation Year doctors attends training on optimal antimicrobial prescribing?'* respondents indicated that collating data on continuing education for doctors would be very difficult. They reported that their Trusts did not have mechanisms in currently in place for recording these data *(see section 4.5.2.5)*.

The item/respondent map for Domain 5 *(see figure 5.7)* showed that the distribution of the items in domain 5 was positively skewed and the NHS trusts were negatively skewed towards the bottom of the operational range for domain 5. In other words, the items in domain 5 were generally more difficult for NHS trusts to report compliance to the implementation strategies for education and training as stipulated by the ASAT. Item Q5.16 which examined whether competency assessment or revalidation was carried out for all antimicrobial prescribers was located at the top of the operational range for domain 5. This indicated that this item received the least amount of positive scores or *'yes'* responses. Most NHS trusts (32/33) reported compliance to item Q5.2 which asked NHS trusts if antimicrobial prescribers were signposted to the location of guidelines and formularies at induction. Since most NHS trusts reported compliance with this item, it was located at the bottom of the operational range for domain 5.

5.5.5.1 Removal of items (Domain 5)

As previously discussed, there were two items that were misfitting in this domain *(see table 5.21)*. However, it was found that the removal of item Q5.10a did not improve the infit statistics of domain 5. Therefore, it was decided to investigate the behaviour of items after the removal of item Q5.9. Again, it was observed that the removal of this item did not improve the overall item fit for this domain. From previous studies, it was noted that there were other items in domain 5 which similarly examined whether an update in optimal prescribing was *'mandated'* or *'available'* for staff groups involved in antimicrobial prescribing. As a result, it was decided that due to the good distribution observed between items and NHS trusts, the removal of items would be conducted based on the results of the qualitative studies previously

conducted in this programme of work as suggested by the guidelines produced by Wolfe (2007)[274;277] where both item fit and cognitive modelling could be used to investigate model fit. Therefore, items Q5.5, Q5.7 and Q5.9 were removed from Domain 5 because in previous studies, respondents reported that these questions were potential duplicates of each other *(see section 3.10.1)*.

Table 5.20 - ITEM STATISTICS (Domain 5): Removal of Q5.5, Q5.7 and Q5.9

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
5.1	19	33	-0.79	0.38	0.95	-0.40	0.91	-0.20
5.2	31	33	-4.04	1.03	1.02	0.30	0.80	0.20
5.3	29	33	-2.84	0.62	1.06	0.30	1.20	0.50
5.4	5	33	1.60	0.53	1.04	0.20	0.91	0.00
5.6	9	33	0.72	0.42	1.04	0.20	0.90	-0.30
5.7	15	33	1.92	0.59	0.92	0.00	0.68	-0.40
5.10	77	33	-1.27	0.21	1.07	0.30	0.76	-0.20
5.10a	39	33	-0.10	0.17	1.55	2.60	1.52	1.30
5.11	42	31	-0.29	0.17	0.86	-0.70	0.86	-0.10
5.11a	16	31	0.70	0.24	1.03	0.20	0.72	-0.20
5.12	29	31	0.02	0.17	0.96	-0.10	0.66	0.00
5.12a	11	31	0.82	0.28	0.98	0.20	0.62	0.20
5.13	22	32	0.30	0.19	0.75	-0.80	0.44	-0.60
5.13a	13	32	0.80	0.27	0.83	-0.20	0.91	0.20
5.14	21	32	0.36	0.21	1.01	0.10	1.44	0.80
5.14a	14	32	0.77	0.27	0.91	0.00	0.56	-0.04
5.15	58	33	-0.64	0.16	0.97	-0.10	0.80	-0.10
5.15a	48	33	-0.37	0.16	1.00	0.10	0.82	-0.10
5.16	3	33	2.32	0.67	**1.49**	1.00	1.22	0.50
Mean	25.8	32.4	0.00	0.35	1.02	0.20	0.88	0.10
S.D	19.3	0.00	1.49	0.23	0.19	0.70	0.28	0.50

Nb. Misfitting items in Table 5.20 have been highlighted in blue.

Improved item fit was demonstrated following the removal of these items. However there was an underfit observed with item Q5.16 (INFIT MNSQ 1.49) *(see table 5.20).* Item/respondent map shows an improved distribution between items and NHS trusts after removal of items Q5.5, Q5.7 and Q5.9 *(see figure 5.8)*. The distribution of the NHS trusts was normally distributed and the items also exhibited a normal distribution where both the NHS trust and item means located in a closer proximity to each other. This distribution indicated that the measure was improved due to removal of these items.

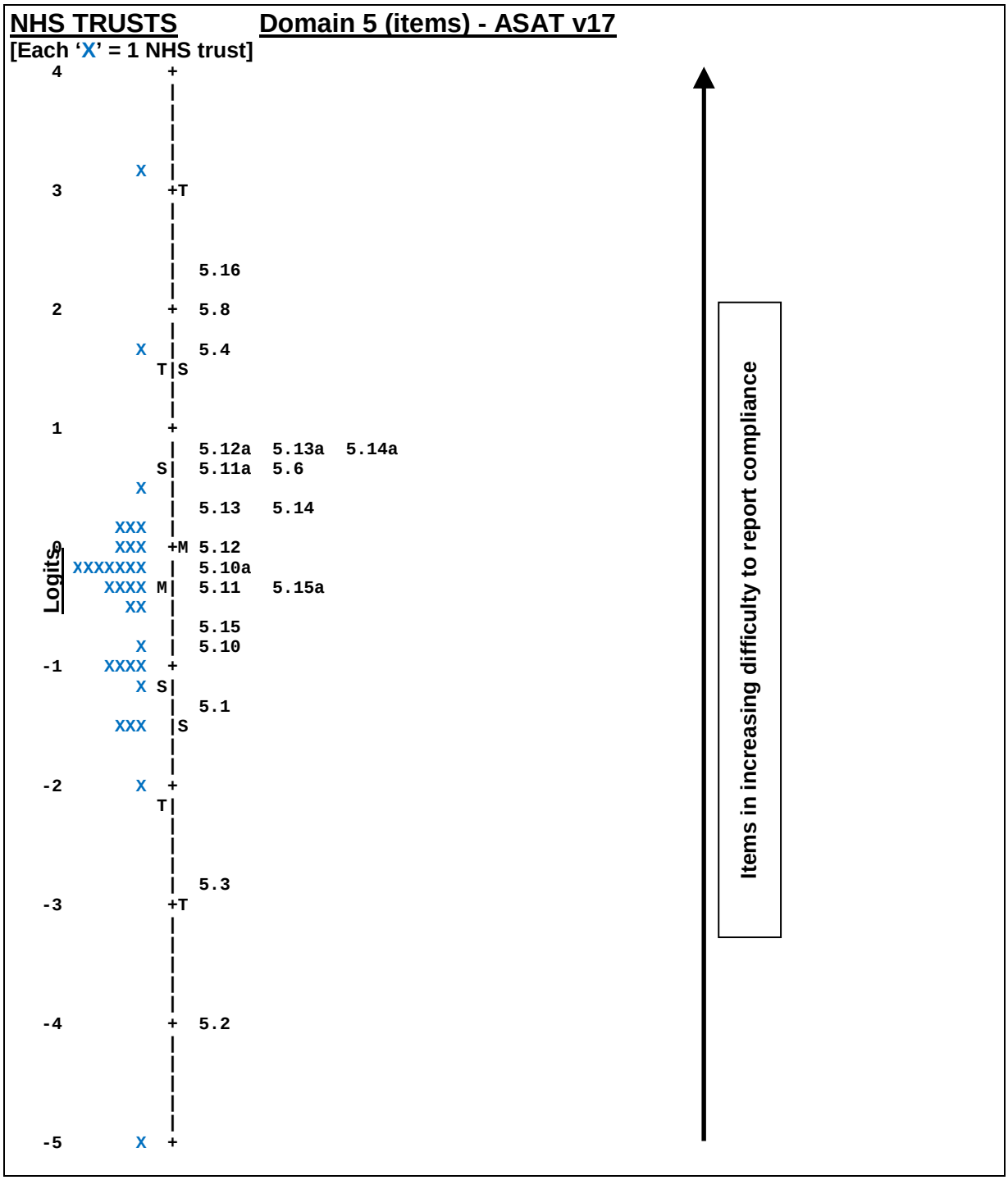

Figure 5.8 – Respondents/items map (Domain 5): Removal of Q5.5, Q5.7 and Q5.9

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust
#	Two NHS trusts

Table 5.21 - NHS TRUST STATISTICS (Domain 5): Removal of Q5.5, Q5.7 and Q5.9

NHS trust	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT MNSQ
1	42	19	3.25	1.07	0.69	0.00	0.18	-0.50
2	22	19	0.16	0.25	0.55	-1.50	0.42	-1.00
3	7	19	-1.09	0.38	0.43	-1.00	0.24	-0.80
4	8	19	-0.96	0.35	1.86	1.40	1.23	0.50
5	19	19	-0.04	0.26	1.81	2.00	1.42	0.80
6	39	19	1.70	0.49	0.39	-0.60	0.34	-0.20
7	17	19	-0.17	0.26	0.54	-1.50	0.46	-1.00
8	17	19	-0.17	0.26	0.70	-0.80	1.06	0.30
9	8	19	-0.96	0.35	1.11	0.40	0.63	-0.10
10	14	19	-0.39	0.28	0.68	-0.80	0.40	-1.00
11	15	19	-0.31	0.27	0.80	-0.50	0.78	-0.20
12	0	19	-5.42	1.98	**MINIMUM MEASURE**			
13	5	19	-1.43	0.46	0.27	-1.20	0.19	-0.50
14	8	19	-0.96	0.35	1.56	1.00	0.98	0.30
15	17	19	-0.17	0.26	1.16	0.60	0.83	-0.10
16	5	19	-1.43	0.46	0.71	-0.20	0.19	-0.50
17	9	19	-0.84	0.33	0.70	-0.50	1.62	0.90
18	28	19	0.55	0.26	0.74	-0.80	-0.68	-0.20
19	14	13	0.03	0.36	0.43	-1.30	0.38	-0.07
20	16	19	-0.24	0.27	0.97	0.10	1.33	0.70
21	15	19	-0.31	0.27	0.97	0.00	1.58	1.00
22	21	19	0.09	0.25	2.47	3.20	3.66	2.90
23	17	19	-0.17	0.26	0.87	-0.30	1.18	0.50
24	15	19	-0.31	0.27	1.45	1.20	1.27	0.60
25	8	19	-0.96	0.35	2.20	1.80	2.02	1.20
26	12	19	-0.55	0.29	0.66	-0.80	0.36	-1.00
27	12	13	-0.23	0.36	1.57	1.20	0.84	0.00
28	18	19	-0.10	0.26	0.49	-1.70	0.35	-1.30
29	13	19	-0.47	0.28	1.38	1.00	1.23	0.50
30	20	19	0.03	0.26	0.71	-0.81	0.75	-0.30
31	21	19	0.09	0.25	0.80	-0.50	0.51	-0.80
32	5	19	-1.43	0.46	1.00	0.20	0.72	0.20
33	3	19	-2.01	0.65	0.43	-0.30	0.25	-0.30
Mean	14.8	18.6	-0.46	0.40	0.97	0.00	0.88	0.00
S.D	9.0	1.40	1.27	0.32	0.54	1.10	0.69	0.80

The NHS trusts (respondent) statistics indicated that this domain possessed the ability to discriminate between NHS trusts and there was only one trust that obtained a minimum measure for this domain *(see table 5.21)*. These results justified the inclusion of the remaining items in this domain. However, consideration should be given to the removal of items Q5.5, Q5.7 and Q5.9 in further iterations of the ASAT.

5.5.6 DOMAIN 6 (Antimicrobial Pharmacist)

Item Q6.1 was dropped from the analysis by WINSTEPS because each respondent indicated that their NHS Trust had an AMP in post, hence, reporting perfect scores in response to this question. Item Q6.3 (INFIT MNSQ 1.53) appeared to be underfitting the model. Item Q6.8 (INFIT MNSQ 0.57) appeared to be a redundant item as it was overfitting the model *(see table 5.22)*. All other items within this domain appear to be fulfilling the assumption of unidimensionality by measuring the unitary concept of the role of antimicrobial pharmacists in implementing hospital-based ASPs.

Table 5.22 - ITEM STATISTICS (DOMAIN 6)

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
6.2	33	33	1.27	0.82	0.86	0.00	1.62	0.90
6.3	64	33	0.04	0.32	**1.53**	2.00	1.45	1.70
6.4	25	33	-0.15	0.48	1.01	0.10	0.77	-0.10
6.5	29	33	-1.32	0.63	0.91	-0.10	0.98	0.30
6.6	10	33	2.68	0.45	0.88	-0.50	0.69	-0.50
6.7	23	33	0.28	0.45	0.96	-0.10	0.72	-0.30
6.8	36	33	-0.39	0.50	**0.57**	-1.80	0.33	-0.80
6.9	31	33	-2.43	0.90	0.81	0.00	0.43	0.00
Mean	30.1	33.0	0.00	0.57	0.94	-0.01	0.87	0.10
S.D	14.4	0.00	1.44	0.19	0.25	1.00	0.43	0.80

Nb. Misfitting items in Table 5.23 have been highlighted in blue. Item Q6.1 has been dropped from the analysis by WINSTEPS

The NHS trusts were normally distributed in the item/person maps for Domain 6. However, this distribution was skewed towards the top of the operational range for this domain *(see figure 5.9)*. This indicated that NHS trusts were able to report compliance to the items in domain 6. The question which appeared to be most difficult to report compliance with was item Q6.6 (INFIT MNSQ 0.88) which asked if AMPs had specialist training in infection management. However, item Q6.9 (INFIT MNSQ 0.81) which asked if the hospital's AMP was supported in attending continuing education in infection management was located at the bottom of the operational range for domain 6. Since, item Q6.3 appeared to be underfitting the model, it was decided to remove this item from the dataset and rerun the analysis.

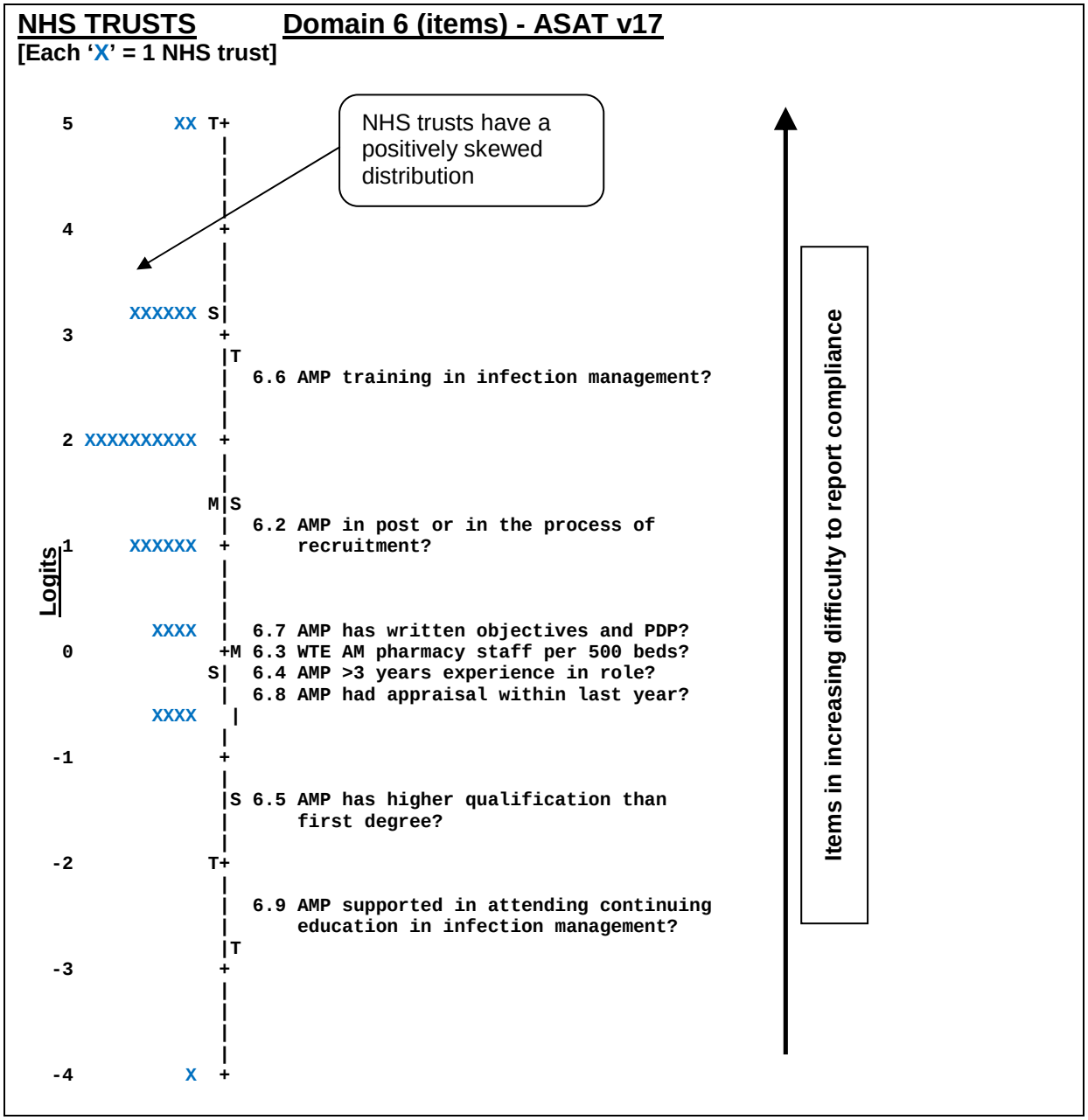

Figure 5.9 -Respondents/items map (Domain 6)

Nb. Abbreviations used, antimicrobial (AM), antimicrobial pharmacist (AMP), whole time equivalent (WTE), personal development plan (PDP)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust
#	Two NHS trusts

5.5.6.1 Removal of Q6.3 (Domain 6)

Item Q6.3 was removed from domain 6 and the item fit statistics were re-analysed. It was observed that the removal of these items resulted in improved fit for only two items. However, item Q6.9 was slightly misfitting with an INFIT MNSQ statistic of

1.40 *(see table 5.23)*. The removal of item Q6.3 did not appear to significantly improve the model so therefore they will be retained in further iterations of the ASAT.

Table 5.23 - ITEM STATISTICS: (Domain 6) Removal of Q6.3

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
6.2	33	33	6.76	1.04	0.94	0.20	0.26	-0.30
6.4	25	33	-1.02	0.55	1.13	0.50	1.18	0.60
6.5	29	33	-2.58	0.73	0.94	0.00	9.90	7.50
6.6	10	33	2.79	0.56	0.56	-1.30	0.34	-0.70
6.7	23	33	-0.45	0.52	0.97	0.00	0.62	0.10
6.8	36	33	-1.34	0.58	0.62	-1.30	0.30	-0.30
6.9	31	33	-4.15	1.12	**1.40**	0.70	0.60	0.10
Mean	25.3	33.0	0.00	0.73	0.94	-0.20	1.88	1.0
S.D	7.0	0.0	3.39	0.23	0.27	0.80	3.29	2.7

Nb. Misfitting items in Table 5.23 have been highlighted in blue.

The results of the INFIT MNSQ statistics indicated that item Q6.1 was a redundant item in domain 6. The reason for this overfit could be respondents interpreted this question as a duplicate of Q6.2 *(see section 3.10.1)* therefore this interpretation negatively impacted on the question's ability to contribute to the measure.

Item Q6.3 which asked '*How many whole time equivalent (WTE) pharmacy staff per 500 beds are spent on antimicrobial duties?* was underfitting the model.

Respondents in Study 1 indicated that this question was difficult to answer for the following reasons *(see section 3.8.2)*:

- lack of clarity to which staff groups which were targeted by Q6.3. Respondents queried whether this question was targeted at antimicrobial pharmacists and pharmacy technicians or antimicrobial pharmacist only
- some antimicrobial pharmacist posts are part-time so respondents were unsure of how to calculate the '*whole time equivalent (WTE) pharmacy staff per 500 beds'* ratio
- some Trusts had more than or less than 500 beds so therefore respondents indicated that the calculation was difficult in these instances

Also, it was observed that the item/respondent map produced after the removal of item Q6.8 did not impact the item hierarchy of the distribution of NHS trusts in domain 6 *(see figure 5.10)*. In other words, the items remained in the same logit positions prior to the removal of Q6.8.

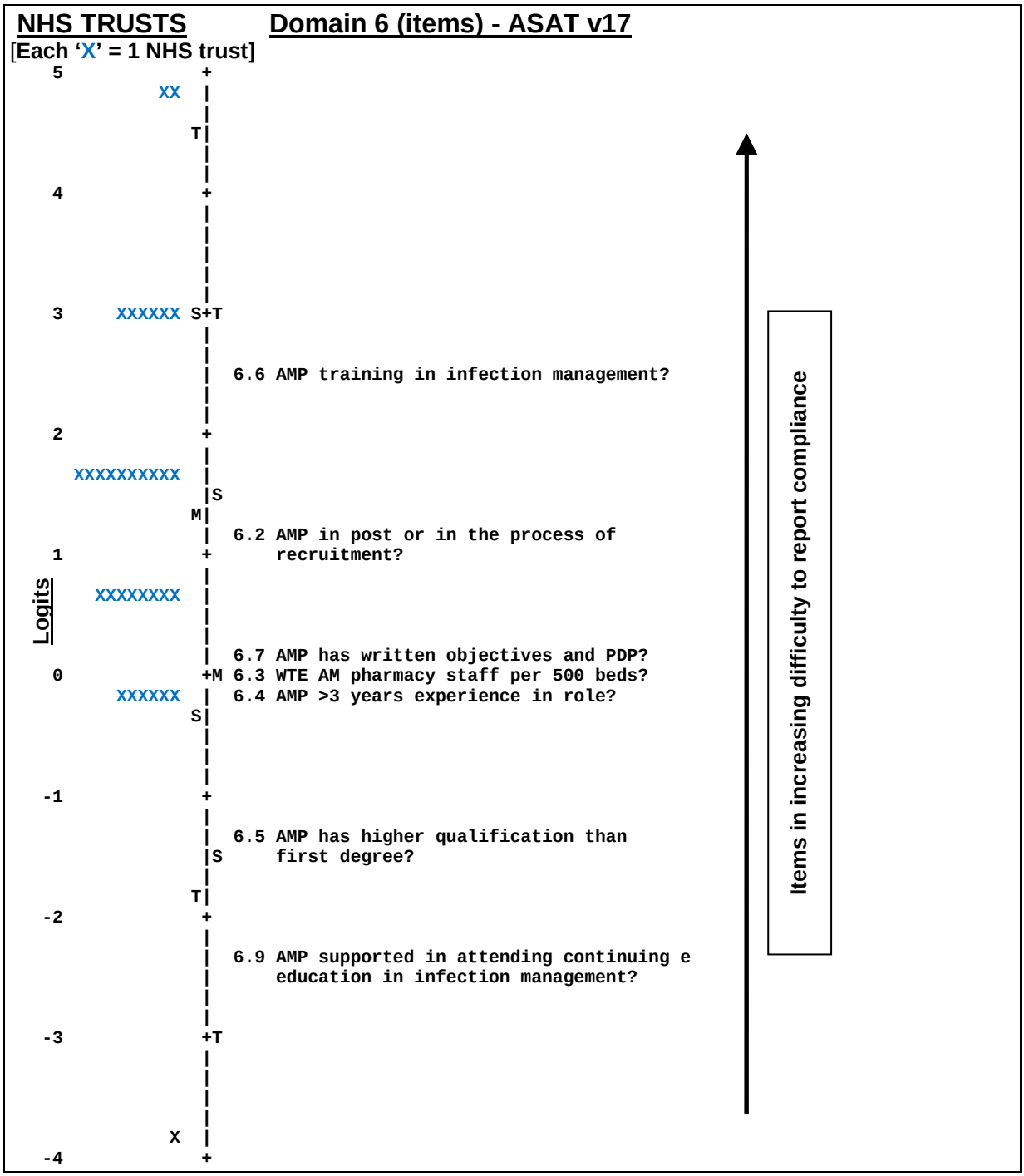

Figure 5.10 – Respondents/items map (Domain 6): Removal of Q6.8

Nb. Abbreviations used, antimicrobial (AM), antimicrobial pharmacist (AMP), whole time equivalent (WTE), personal development plan (PDP)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust
#	Two NHS trusts

The NHS Trust statistics *(see table 5.24)* indicated that this was a good measure of the antimicrobial pharmacist role in ASPs. There were no minimum or maximum

measures achieved so therefore this domain possesses the ability to discriminate between NHS Trusts.

Table 5.24 - NHS trust STATISTICS (Domain 6)

NHS trust	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT MNSQ
1	10	9	3.17	1.20	0.51	-0.60	0.19	-0.40
2	10	9	3.17	1.20	0.98	0.20	0.36	-0.10
3	8	9	0.92	0.93	0.69	-0.40	0.52	0.00
4	8	9	0.92	0.93	0.53	-0.70	0.37	-0.20
5	9	9	1.91	1.06	0.18	-1.40	0.12	-0.60
6	10	9	3.17	1.20	0.51	-0.60	0.19	-0.40
7	9	9	1.91	1.06	0.18	-1.40	0.12	-0.60
8	11	9	5.00	1.55	0.22	-0.80	0.08	-0.70
9	9	9	1.91	1.06	0.18	-1.40	0.12	-0.60
10	7	9	0.13	0.85	0.65	-0.80	0.44	-0.40
11	8	9	0.92	0.93	0.53	-0.70	0.37	-0.20
12	6	9	-0.57	0.83	2.02	2.00	1.33	0.60
13	6	9	-0.57	0.83	1.25	0.70	0.95	0.20
14	7	9	0.13	0.85	0.65	-0.80	0.44	-0.40
15	7	9	0.13	0.85	0.76	-0.50	0.54	-0.20
16	6	9	-0.57	0.83	0.72	-0.60	0.50	-0.40
17	9	9	1.91	1.06	0.18	-1.40	0.12	-0.60
18	9	9	1.91	1.06	0.18	-1.40	0.12	-0.60
19	8	9	0.92	0.93	0.79	-0.20	0.45	-0.10
20	9	9	1.91	1.06	1.91	1.20	0.85	0.40
21	9	9	1.91	1.06	1.46	0.80	1.30	0.70
22	9	9	1.91	1.06	4.05	2.60	9.90	3.00
23	8	9	0.92	0.93	1.83	1.30	1.48	0.80
24	9	9	1.91	1.06	1.85	1.20	1.09	0.50
25	8	9	0.92	0.93	2.17	1.70	1.27	0.60
26	7	9	0.13	0.85	1.44	1.00	2.18	1.20
27	6	9	-0.57	0.83	2.60	2.70	1.60	0.90
28	10	9	3.17	1.20	0.98	0.20	0.36	-0.10
29	11	9	5.00	1.55	0.22	-0.80	0.08	-0.70
30	10	9	3.17	1.20	0.51	-0.60	0.19	-0.40
31	9	9	1.91	1.06	0.18	-1.40	0.12	0.60
32	2	9	-3.95	1.17	0.95	0.20	0.41	-0.10
33	10	9	3.17	1.20	0.51	-0.60	0.19	-0.40
Mean	8.3	9.0	1.45	1.04	0.98	-0.10	0.86	0.00
S.D	1.8	0.0	1.73	0.18	0.86	1.20	1.68	0.70

5.5.7 DOMAIN 7 (Clinical Microbiologist)

On examination of the fit statistics for Domain 7, it was observed that item Q7.4 (INFIT MNSQ 0.69) was slightly overfitting the model and item Q7.6 (INFIT MNSQ 1.40) was underfitting the model *(see table 5.26)*. Item Q7.2 was dropped from the analysis by WINSTEPS. Rasch modelling was unable to determine the item hierarchy for this item so therefore it was unable to report INFIT MNSQ values for Q7.2. However, this item was retained in the item pool of domain 7 for further analysis that is, to determine its behaviour within the entire item pool of ASAT v17

(see section (5.5.9). Although, these items may not demonstrate good item infit, they may still be informative as part of an ASP evaluation, in order to confirm that some practices are in place. In response to Q7.2, 91% (30/33) of respondents indicated that they had a clinical microbiologist available by phone during a 24-hour period, which accounted for the ceiling effect observed within this domain.

Table 5.25 - ITEM STATISTICS (DOMAIN 7)

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
7.1	32	33	-1.14	1.08	1.12	0.40	1.30	0.60
7.3	30	33	0.33	0.73	0.70	-1.10	0.64	-1.20
7.4	29	32	0.49	0.76	0.69	-1.30	0.65	-1.30
7.5	30	33	0.33	0.73	1.11	0.50	1.19	0.70
7.6	62	33	-0.01	0.52	**1.40**	0.90	1.34	0.70
Mean	36.6	32.8	0.00	0.76	1.01	-0.10	1.02	-0.10
S.D	12.7	0.40	0.59	0.18	0.27	0.90	0.31	0.90

Nb. Misfitting items in Table 5.25 have been highlighted in blue.

Item Q7.6 which asked *'Is advice from a clinical microbiologist or infectious disease physician available by phone?'* was slightly underfitting the model. Most respondents indicated that they had 24-hour access to advice from an infectious disease specialist. Consequently, item misfit may be due to other reasons other than the availability of the infectious disease specialist in NHS trusts. Potentially, this item could be measuring a variable or process external to domain 7.

A ceiling effect was observed on analysis of the item/respondent map for domain 7 *(see figure 5.11)*. This ceiling effect was caused by respondents obtaining maximum scores to items in domain 7. Item Q7.4 (INFIT MNSQ 1.11) appeared to be the most difficult item to report compliance and item Q7.1 (INFIT MNSQ 1.12) appeared to the easiest item to report compliance. It was decided not to delete any of the remaining items from domain 7 because these items produced INFIT MNSQ statistics within the range of 0.7 to 1.3. These items appear to be working well together to define the role of clinical microbiologists in ASPs. However, the assumption of item discrimination was not fulfilled (see figure 5.11) because the items within this domain were endorsed by the participating NHS trusts. In order to improve the item discrimination of this domain, the inclusion of items which evaluate the role of clinical microbiologists more rigorously would have to be included.

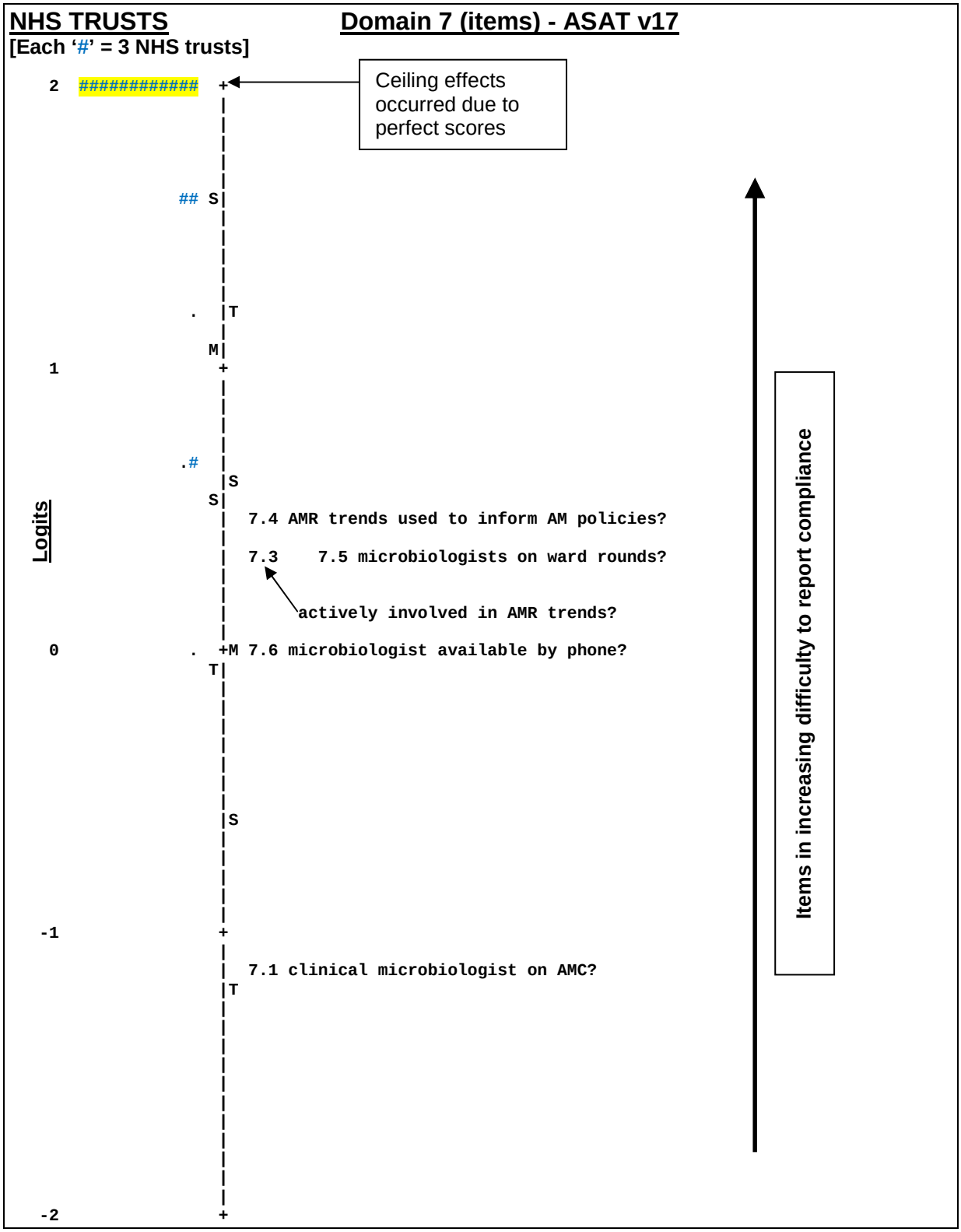

Figure 5.11 – Respondents/items map (Domain 7) *Nb. Abbreviations used; antimicrobial (AM), antimicrobial resistance (AMR), antimicrobial committee (AMC)*

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust
#	Two NHS trusts

The inability to discriminate between NHS trusts was confirmed on examination of the NHS Trust statistics which clearly showed that there were 24 out of 33 NHS trusts which achieved a maximum score for this domain *(see table 5.26)*.

Table 5.26 - NHS trust STATISTICS (DOMAIN 7)

NHS trust	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT MNSQ
1	7	6	2.86	1.85	**MAXIMUM MEASURE**			
2	6	6	1.57	1.09	0.92	0.20	0.87	0.20
3	7	6	2.86	1.85	**MAXIMUM MEASURE**			
4	7	6	2.86	1.85	**MAXIMUM MEASURE**			
5	7	6	2.86	1.85	**MAXIMUM MEASURE**			
6	7	6	2.86	1.85	**MAXIMUM MEASURE**			
7	7	6	2.86	1.85	**MAXIMUM MEASURE**			
8	7	6	2.86	1.85	**MAXIMUM MEASURE**			
9	5	6	0.66	0.85	0.83	-0.20	0.82	-0.20
10	7	6	2.86	1.85	**MAXIMUM MEASURE**			
11	7	6	2.86	1.85	**MAXIMUM MEASURE**			
12	5	6	1.22	1.09	1.33	0.60	2.93	1.70
13	7	6	2.86	1.85	**MAXIMUM MEASURE**			
14	6	6	1.57	1.09	0.92	0.20	0.87	0.20
15	7	6	2.86	1.85	**MAXIMUM MEASURE**			
16	7	6	2.86	1.85	**MAXIMUM MEASURE**			
17	7	6	2.86	1.85	**MAXIMUM MEASURE**			
18	7	6	2.86	1.85	**MAXIMUM MEASURE**			
19	7	6	2.86	1.85	**MAXIMUM MEASURE**			
20	7	6	2.86	1.85	**MAXIMUM MEASURE**			
21	7	6	2.86	1.85	**MAXIMUM MEASURE**			
22	7	6	2.86	1.85	**MAXIMUM MEASURE**			
23	6	6	1.57	1.09	0.91	0.20	0.68	0.00
24	7	6	2.86	1.85	**MAXIMUM MEASURE**			
25	4	6	0.00	0.79	0.98	0.00	0.77	-0.70
26	5	6	0.66	0.85	0.83	-0.20	0.82	-0.20
27	7	6	2.86	1.85	**MAXIMUM MEASURE**			
28	7	6	2.86	1.85	**MAXIMUM MEASURE**			
29	7	6	2.86	1.85	**MAXIMUM MEASURE**			
30	7	6	2.86	1.85	**MAXIMUM MEASURE**			
31	6	6	1.57	1.09	0.91	0.20	0.68	0.00
32	7	6	2.86	1.85	**MAXIMUM MEASURE**			
33	5	6	0.66	0.85	1.86	1.60	1.23	0.60
Mean	6.50	6.0	2.37	1.61	1.05	0.30	1.07	0.20
S.D	0.80	0.2	0.85	0.40	0.32	0.50	0.67	0.60

The removal of item Q7.6 caused items Q7.1 (INFIT MNSQ 1.42) and item Q7.5 (INFIT MNSQ 1.50) to underfit the model and the INFIT MNSQ value for item Q7.2 was inestimably low *(see table 5.27)*.

Table 5.27 - ITEM STATISTICS (DOMAIN 7) Removal of item Q7.6

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
7.1	32	33	-1.52	1.16	**1.42**	0.80	1.56	0.80
7.2	**INESTIMABLE: LOW**							
7.3	30	33	0.36	0.88	0.58	-1.50	0.54	-1.30
7.4	29	32	0.80	1.00	0.50	-1.50	0.46	-1.00
7.5	30	33	0.36	0.88	**1.50**	1.50	1.47	1.20
Mean	30.3	32.8	0.00	0.98	1.00	-0.20	1.01	-0.10
S.D	1.1	0.4	0.89	0.11	0.46	1.4	0.51	1.10

Nb. Misfitting items in Table 5.27 have been highlighted in blue

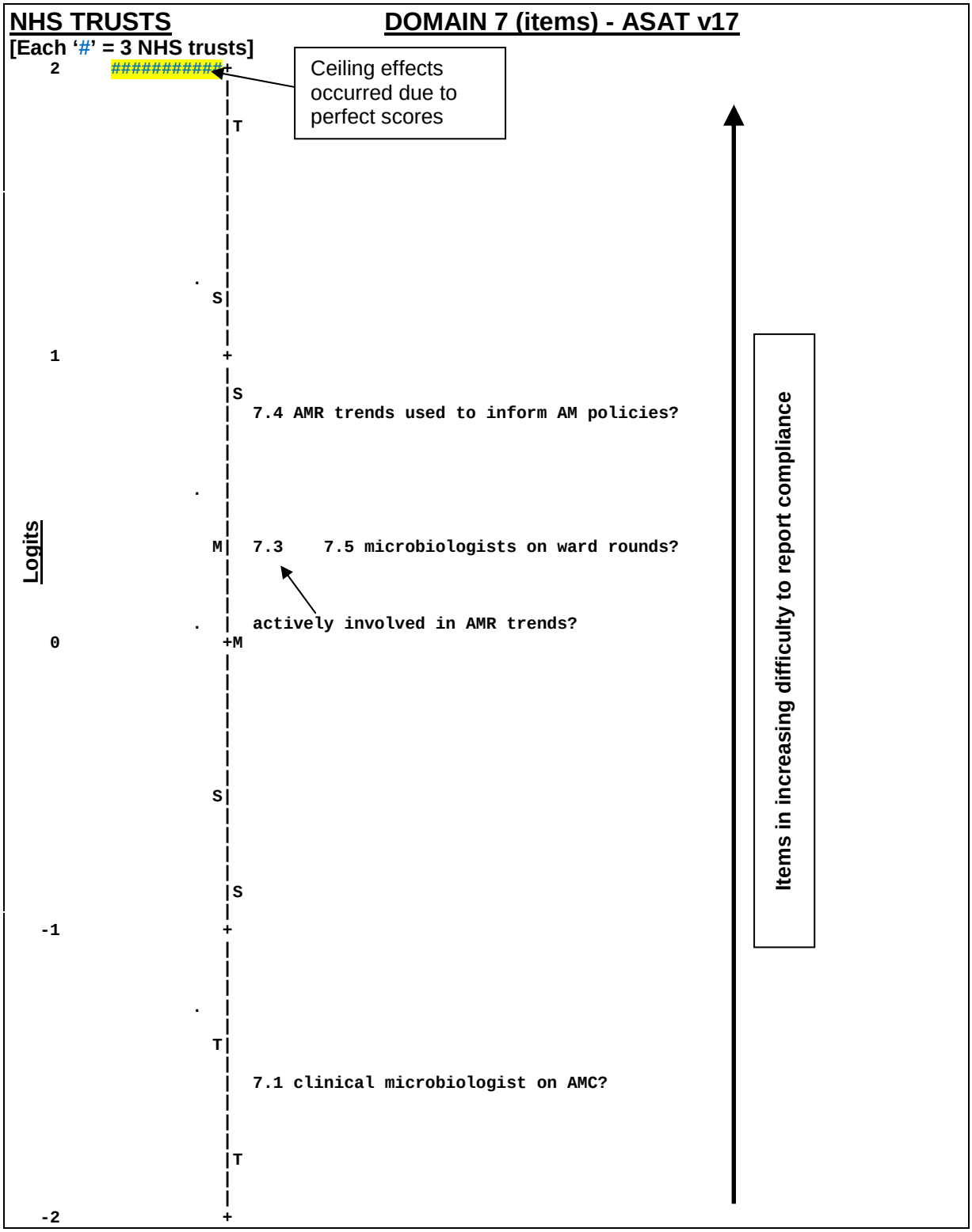

Figure 5.12 - Respondents/items map (Domain 7): Removal of Q7.6 *Nb. Abbreviations used; antimicrobial (AM), antimicrobial resistance (AMR), antimicrobial committee (AMC)*

KEY:

M	Mean NHS trust or item distribution	#	Two or more NHS trusts
S	One standard deviation from the NHS trust or item mean		
T	Two standard deviations from the NHS trust or item mean		

On examination of the item/respondent map, it was observed that a greater ceiling was caused after the removal of Q7.6. As a result, all NHS trusts were located at the top of the operational range for this domain as a result of removing item Q7.6 *(see figure 5.12)*. Therefore, this domain lacked the ability to discriminate between NHS trusts. However, due to the results of the infit statistics, it was decided to retain this item in domain 7 for further analysis.

5.5.8 Domain 8 (Patients, Carers and the Public)

It was observed that item Q8.6 (INFIT MNSQ 0.64) was slightly overfitting the model *(see table 5.28)* after examination of the fit statistics for domain 8. This overfit indicated that this question could be redundant. All other items within Domain 8 appeared to have good fit with infit statistics ranging from INFIT MNSQ 0.99 to 1.24. These items appear to be fulfilling the assumption of unidimensionality (INFIT MNSQ range between 0.7 to 1.3) because they appear to be measuring the unitary concept of implementation strategies used to inform patients, carers and the public.

Table 5.28 - ITEM STATISTICS: ENTRY ORDER (DOMAIN 8)

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
8.1	11	33	1.55	0.44	1.24	0.80	1.26	0.70
8.2	46	29	-0.77	0.37	1.10	0.50	1.14	0.50
8.3	29	29	0.45	0.31	1.04	0.20	1.04	0.20
8.4	48	28	-0.17	0.51	1.02	0.20	1.06	0.30
8.5	50	28	-0.70	0.52	0.99	0.00	0.94	-0.10
8.6	33	28	-0.37	0.32	**0.64**	-1.20	0.64	-1.20
Mean	36.2	29.2	0.00	0.41	1.01	0.10	1.01	0.10
S.D	13.7	1.80	0.80	0.08	0.18	0.60	0.19	0.60

Nb. Misfitting items in Table 5.28 have been highlighted in blue.

The slight overfit observed with item Q8.6 which could be due to respondents interpreting this question as a duplication of item Q8.3 *(see section 3.10.1)*. Both of the questions asked if patients received an explanation about the risks and side-effects of antimicrobial chemotherapy, as an inpatient and at discharge. Consequently, the ability of item Q8.6 to contribute to the measure was negatively affected therefore this accounted for the overfit of this question.

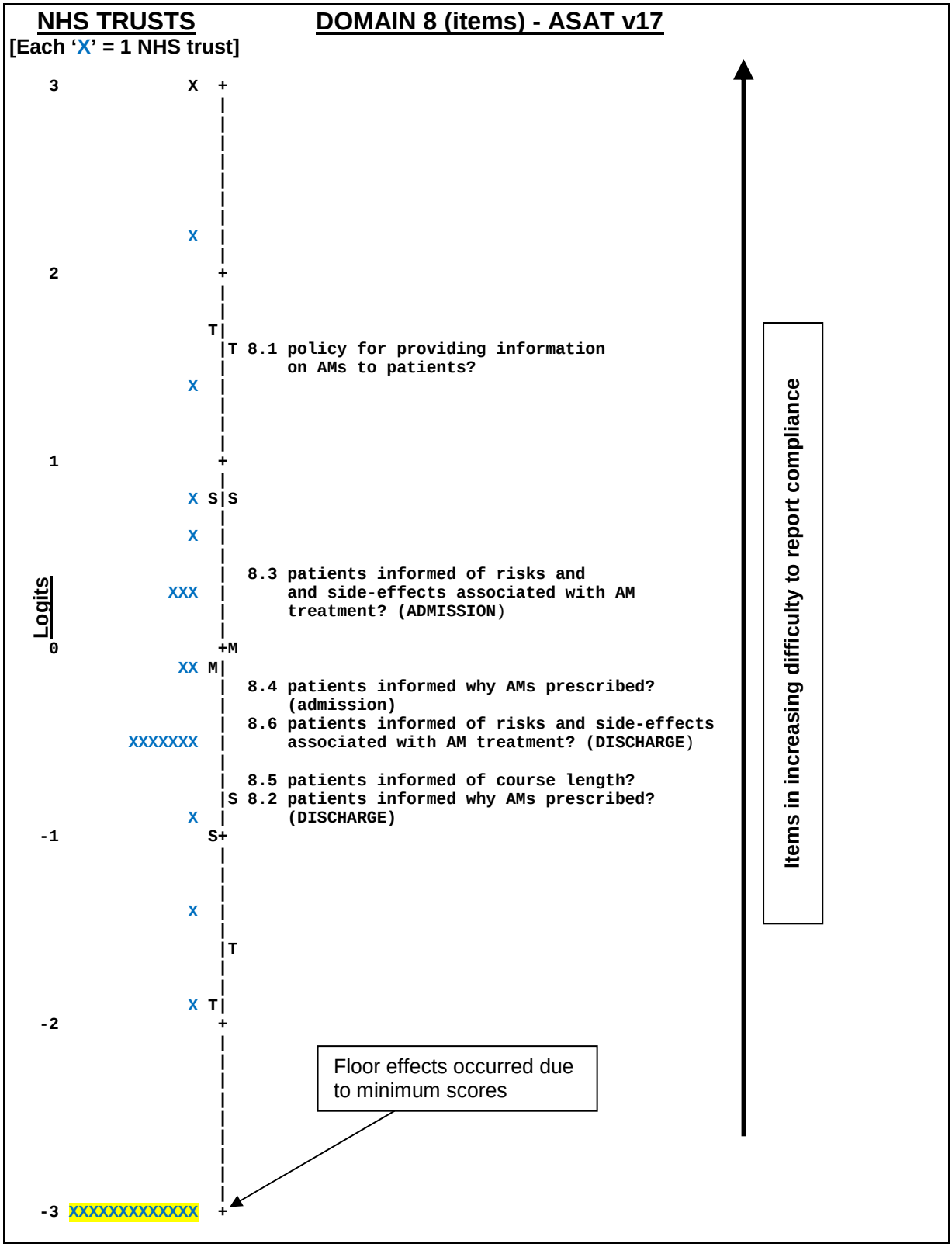

Figure 5.13 – Respondents/items map (Domain8)

Nb. Abbreviations used; antimicrobial(s) (AMs)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust
#	Two NHS trusts

However, on examination of the item/person map for Domain 8, a floor effect was observed *(see figure 5.13)* which indicated poor item discrimination for this domain. This floor effect resulted from respondents achieving minimum scores for this domain; this was expected due to respondents in previous studies indicating that it would be very difficult to collate these data required to answer these questions. This was confirmed by the NHS trust statistics obtained for this domain *(see table 5.29)* where 13/33 NHS trusts achieved the minimum measure of -3.26. Hence, the minimum measure indicated that these trusts were unable to report compliance to the requirements for providing information to patients as described by the ASAT operational range for this domain.

Table 5.29 - NHS trust STATISTICS: (Domain 8)

NHS trust	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT MNSQ
1	12	6	0.33	0.69	0.49	-0.90	0.60	0.80
2	0	6	-3.26	1.84	**MINIMUM MEASURE**			
3	9	6	-0.92	0.64	0.64	-0.70	0.64	-0.70
4	0	6	-3.26	1.84	**MINIMUM MEASURE**			
5	0	6	-3.26	1.84	**MINIMUM MEASURE**			
6	0	6	-0.38	2.04	**MINIMUM MEASURE**			
7	0	1	-0.38	2.04	**MINIMUM MEASURE**			
8	10	6	-0.52	0.63	2.19	2.10	1.99	2.00
9	15	6	2.18	0.92	0.24	-1.40	0.19	-0.90
10	0	6	-3.26	1.84	**MINIMUM MEASURE**			
11	10	6	-0.52	0.63	1.21	0.60	1.10	0.40
12	12	6	-3.26	1.84	**MINIMUM MEASURE**			
13	8	6	-1.35	0.68	0.74	-0.40	1.45	0.90
14	11	6	-0.11	0.65	0.72	-0.40	0.72	-0.60
15	10	6	-0.52	0.63	0.60	-0.80	0.61	-0.90
16	10	6	-0.52	0.63	0.30	-1.90	0.39	-1.80
17	0	6	-3.26	1.84	**MINIMUM MEASURE**			
18	14	6	1.44	0.81	0.85	0.00	0.58	-0.40
19	7	6	-1.88	0.78	1.30	0.60	1.80	1.10
20	0	6	-3.26	1.84	**MINIMUM MEASURE**			
21	0	6	-3.26	1.84	**MINIMUM MEASURE**			
22	12	6	0.33	0.69	1.65	1.10	1.38	0.80
23	13	6	0.84	0.74	0.90	0.10	0.79	-0.20
24	0	6	-3.26	1.84	**MINIMUM MEASURE**			
25	11	6	-0.11	0.65	0.72	-0.40	0.72	0.60
26	0	1	-0.38	2.04	**MINIMUM MEASURE**			
27	0	1	-0.38	2.04	**MINIMUM MEASURE**			
28	10	6	-0.52	0.63	0.60	-0.80	0.61	-0.90
29	10	6	-0.52	0.63	0.60	-0.80	0.61	-0.90
30	12	6	0.33	0.69	1.65	1.10	1.97	1.70
31	5	3	0.62	0.95	3.72	2.20	3.94	2.30
32	10	6	-0.52	0.63	0.60	-0.80	0.61	-0.90
33	18	6	4.16	1.96	**MAXIMUM MEASURE**			
Mean	6.6	5.3	-0.87	1.21	1.04	-0.10	1.09	0.00
S.D	5.7	1.7	1.79	0.60	0.80	1.10	0.85	1.10

There was also one NHS trust achieving the maximum measure for domain 8. Some of the NHS trusts were normally distributed around the items which indicated that the items within this domain possessed some ability to discriminate between NHS trusts. However, this distribution was slightly skewed towards the bottom of the operational range for this domain.

The removal of item Q8.6 caused further instability in the model for domain 8. For example, the INFIT MNSQ for item Q8.3 increased from 1.04 to 1.40 *(see table 5.30)*, resulting in item Q8.6 underfitting the model.

Table 5.30 - ITEM STATISTICS (DOMAIN 8): Removal of item 8.6

Item	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
8.1	11	33	1.40	0.43	1.04	0.20	1.08	0.30
8.2	46	29	-0.80	0.36	0.91	-0.20	0.97	0.00
8.3	29	29	0.35	0.31	**1.40**	1.40	1.41	1.30
8.4	48	28	-0.22	0.51	0.82	-1.10	0.82	-0.90
8.5	50	28	-0.73	0.51	0.83	-1.00	0.78	-0.80
Mean	36.8	29.4	0.00	0.42	1.00	-0.10	1.01	0.00
S.D	14.9	1.9	0.81	0.08	0.22	0.90	0.23	0.80

Nb. Misfitting items in Table 5.30 have been highlighted in blue.

As a result, it was decided to retain item Q8.6 in domain 8 for further iterations of the ASAT.

5.5.9 Analysis of the fit statistics of ASAT v17 (overall)

The next stage of Rasch modelling was to determine whether all the items in the ASAT were measuring the single latent variable, that is, ASPs. In terms of the ASAT, the underlying variable was the strategies used for implementing ASPs in NHS trusts. The next stage of Rasch modelling was to examine the item fit and item hierarchy from the respondent/item maps of the entire pool of items within ASAT v17. There were six items dropped from the analysis by WINSTEPS due to the perfect scores submitted by NHS trusts to these items *(see table 5.32)* because Rasch modelling was unable to produce estimates for these items. On analysis of the INFIT MNSQ statistics for ASAT v17, it was observed that there were three items Q5.10a (INFIT MNSQ 1.47), Q5.14 (INFIT MNSQ 1.33) and Q5.15 (INFIT MNSQ 1.33) underfitting the model. These items were investigated to determine whether their removal improved the model *(see section 5.5.10)*. There were no items which were overfitting the model.

On examination of the respondent/item maps for ASAT v17 *(see figure 5.14)*, it was observed that item Q5.16 was the most difficult item to report compliance.

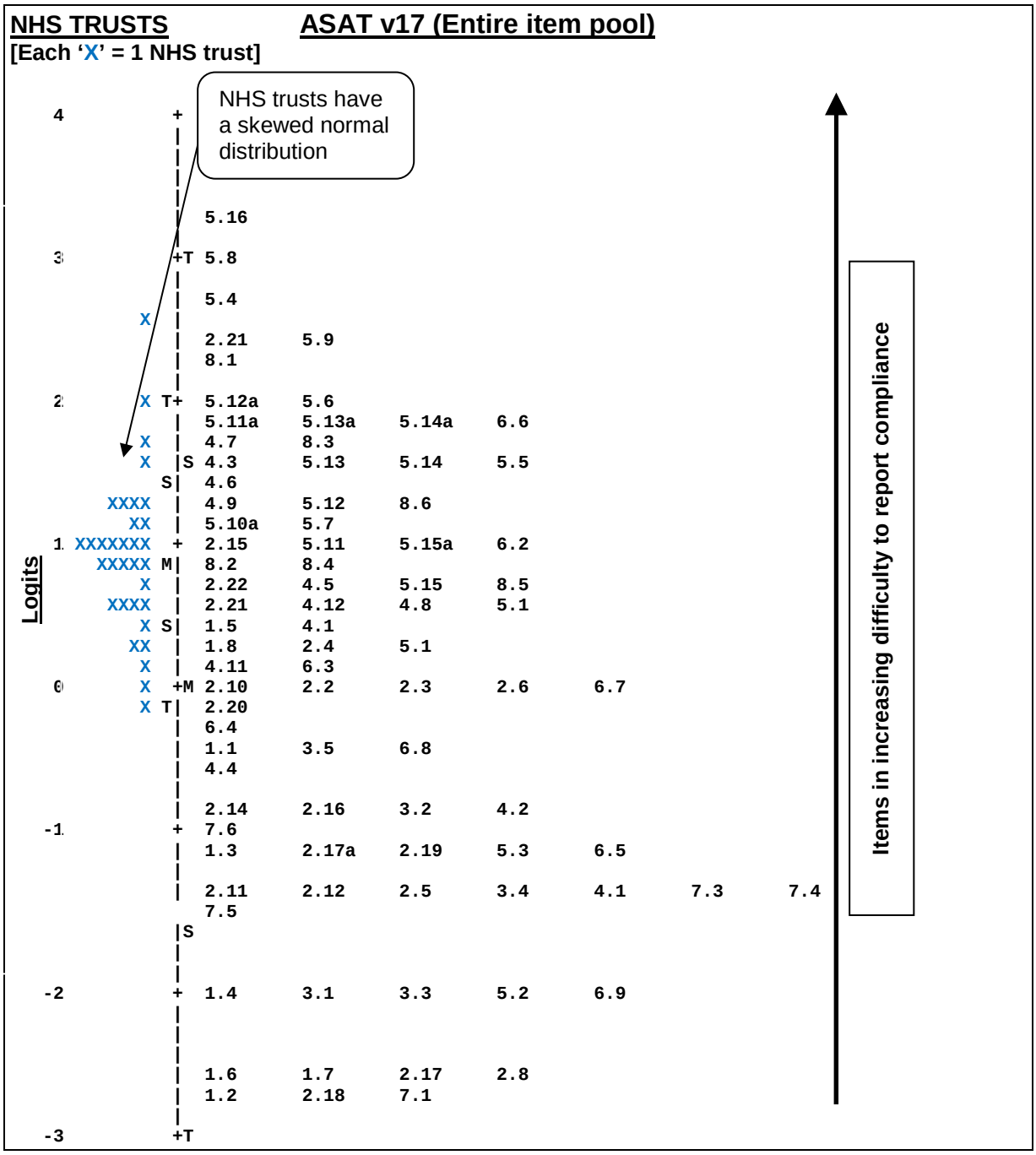

Figure 5.14 – Respondents/items map (ASAT v17)

Nb. Items Q2.1, Q2.7, Q2.9, Q2.13, Q6.1 and Q7.2 were 'dropped' from the analysis by WINSTEPS

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust
#	Two NHS trusts

Items Q1.2, Q2.18 and 7.1 were easiest to report compliance as these items were located at the bottom of the operational range for ASAT v17. The NHS trusts were normally distributed which indicated that the items in ASAT v17 were able to discriminate between NHS trusts.

5.5.10 Summary of Rasch modelling (ASAT v17)

Each domain within ASAT v17 contained items which were misftting the model except for domain 3. Further analyses conducted after the removal of misfitting items generally led to improved item fit for ASAT v17. The respondent separation and reliability was good for domains 2, 4, 5, and 6 *(see table 5.31)* which indicated that these domains were sensitive enough to distinguish between high and low performing NHS trusts.

Table 5.31: Respondent (NHS trust)/item separation for ASAT v17

ASAT v17	Respondent separation	Respondent reliability	Item separation	Item reliability
Domain 1	0.44	0.16	2.00	0.80
Domain 2	1.75	0.73	2.05	0.81
Domain 3	0.00	0.00	0.61	0.27
Domain 4	1.29	0.62	2.41	0.85
Domain 5	1.95	0.79	3.27	0.91
Domain 6	1.06	0.53	2.17	0.82
Domain 7	0.00	0.00	0.00	0.00
Domain 8	0.46	0.17	1.56	0.71

In other words, there was a high probability that NHS trusts with high scores possessed a higher ability to implement ASPs than trusts with low scores. However, domain 1, 3, 7 and 8 were not sensitive enough to discriminate between NHS trusts where domains 3 and domain 7 possessing the least ability. These low values resulted in low R^2 (Pearson correlation coefficient) in the linear regression models conducted as part of this programme of work. It is recommended that a larger sample size would be required to increase the reliability of these domains.[297;307] The item separation was good for each domain within ASAT v17 except for domains 3 and 7 *(see table 5.32)*. The low values for domains 3 and 7 indicated that the sample size was potentially not large enough the confirm item difficulty hierarchy. It is recommended that increasing the length of the survey/questionnaire could overcome low item separation and reliabilty.[297;307] However, ASAT v17 contains 91 items so therefore increasing the length of the questionnaire was not feasible.

As previously discussed, the INFIT MNSQ statistics were analysed for domain 1 to domain 8 of ASAT v17 in order to identify any misfitting items. The examination of the fit indices of ASAT v17 showed that there were items which received perfect scores and these were subsequently *'dropped'* from the analyses *(see table 5.33)*. Also, items which were either underfitting or overfitting the model were investigated to determine whether their removal either improved or negatively affected the item fit of the model *(see table 5.32)*. The findings from these analyses were presented in section 5.5.1 to section 5.5.8 and demonstrated that each domain contained items which were productive for measurement. Only 13/91 items were either misfitting the model or dropped due to perfect scores. In instances where there was item misfit identified, it was shown that the removal of these items resulted in improved item fit.

Table 5.32 - Misfitting and *'dropped'* items of each domain of ASAT v17 and also the overall pool of items within ASAT v17

DOMAIN	DROPPED ITEMS (perfect scores)	MISFITTING ITEMS	
		Overfitting items	Underfitting items
1	-	-	Q1.3, Q1.4
2	Q2.1, Q2.7, Q2.9, Q2.13	Q2.18	Q2.17
3	-	-	-
4	-	Q4.1	Q4.8
5	-	-	Q5.9, Q5.10
6	Q6.1	Q6.8	Q6.3
7	Q7.2	-	Q7.6
8	-	Q8.6	-
Overall ASAT v17	Q2.1, Q2.7, Q2.9, Q2.13, Q6.1, Q7.2	-	Q5.10a, Q5.14, Q5.15

Subsequent to the Rasch modelling conducted for each domain within ASAT v17 and also fit statistics for the entire item pool of ASAT v17, it was decided to investigate the behaviour of the items after the removal of items Q5.10a, Q5.14, Q5.15 and also to generate a number of recommendations for the next iteration of the ASAT *(see section 5.5.11)*. These recommendations were based on the results of the Rasch modelling conducted on ASAT v17 and were supported by the qualitative evidence collated in Study 1 and Study 2 of this programme of work.

5.5.11 The identification of the item pool (Productive for measurement) for the proposed ASAT v18

The investigation into the construct validity of ASAT v17 has highlighted those items which are able to discriminate between NHS trusts i.e. productive for measurement

(item discrimination) and those items which together measured the unitary concept under investigation (unidimensionality). Although, the ASAT was not initially designed for this purpose, if, in the future, there were plans to conduct a comparative analyses between NHS trusts in England, then there are items within the ASAT which would be useful for these analyses. Also, it was reported to the researcher that the ASAT was currently being used by antimicrobial pharmacists groups to compare their performance against each other.

'*The ASAT is already being used as a benchmarking instrument in a number of regions. Antimicrobial pharmacists are working together through local networks to compare their outputs*'[334]

Therefore, in order to determine the items (productive for measurement) that should be included in future iterations, further Rasch modelling were conducted based on the results of analyses of the overall item pool of ASAT v17 *(see section 5.5.9)*.

The fit statistics of each domain was previously investigated *(see section 5.5.1 to 5.5.8)* so therefore it was unnecessary to rerun those analyses.

Section 5.5.9 presented the results of the overall fit statistics of ASAT v17 and these results showed that there were three items (Q5.10a, Q5.14 and Q5.15) which were underfitting the model. Therefore, it was decided to analyse the fit statistics after the removal of Q5.10a, Q5.14 and Q5.15 iteratively *(see figure 5.15).* This was done in order to generate recommendations for the items which should be included in the next iteration of the ASAT, that is, ASAT v18. This identification of the underfitting items from the analysis of the item pool of ASAT v17 represented the first stage (Stage 1) of developing ASAT v18 *(see figure 5.15)*. Items which received perfect scores were *'dropped'* from the analyses by WINSTEPS, that is, items Q2.1, Q2.7, Q2.9, Q2.13, Q6.1 and Q7.2.

The second stage of the analysis was to examine the behaviour of the items after the removal of item Q5.10a *(see figure 5.15)*. On examination of the item statistics, it was observed that the removal of this item did not result in an underfit or overfit of the remaining items. The third stage of the analysis was to examine the behaviour of items after the removal of item Q5.14 and this also resulted in no misfitting items *(see figure 5.15)*. The fourth stage of the analysis was to examine the item fit after the removal of item Q5.15 and this resulted in the underfit of item Q5.15a (INFIT MNSQ 1.42). Subsequently, item Q5.15a was removed from the dataset and the item fit statistics were re-analysed.

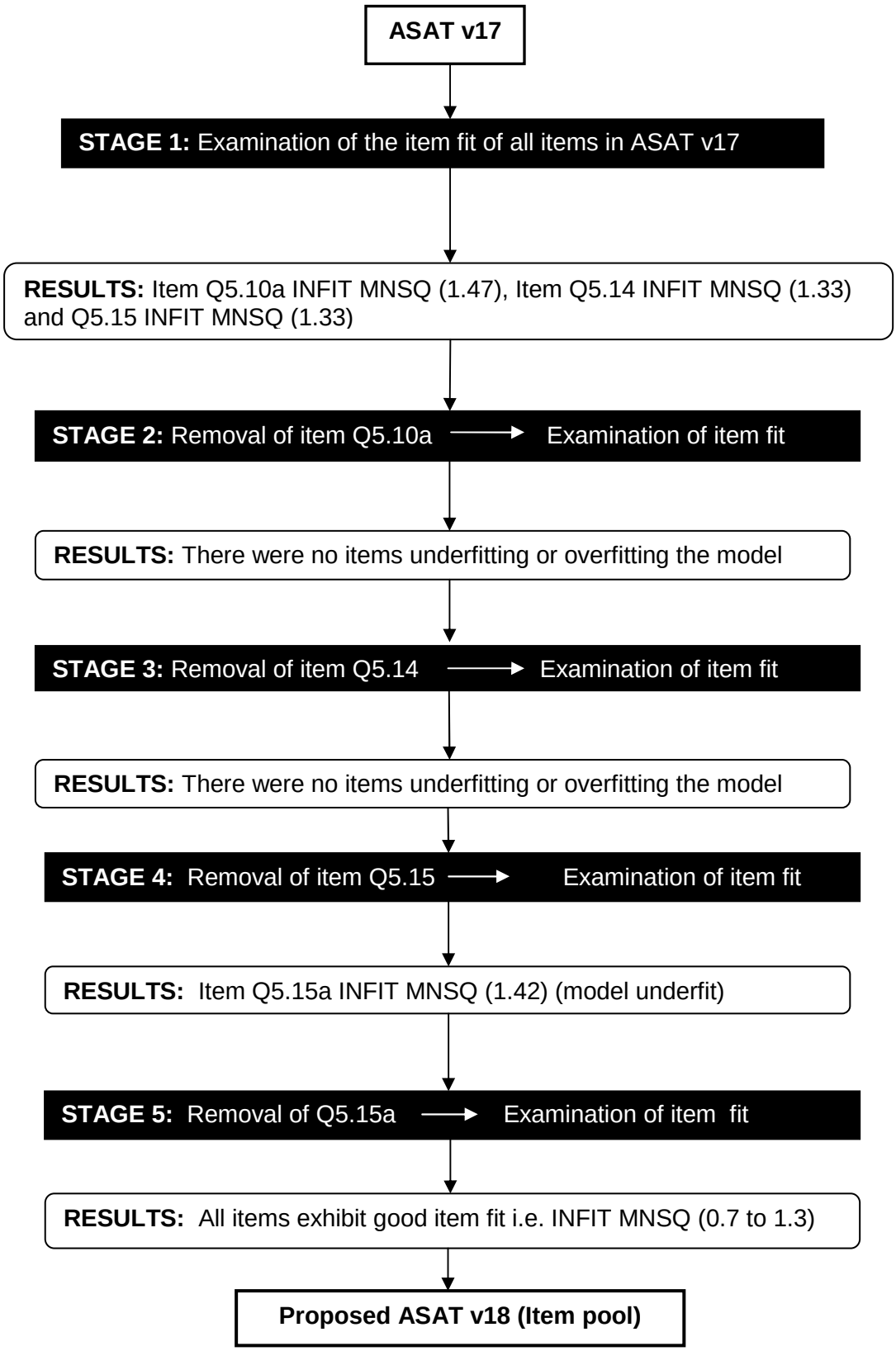

Figure 5.15 - The iterative process for the development of the proposed ASAT v18 from ASAT v17

The item fit statistics showed that there was good infit of the remaining items *(see figure 5.16)* where the INFIT MNSQ range was 0.79 to 1.23. Consequently, it was

decided that the remaining items should be retained in the item pool *(see figure 5.16)* for the next iteration of the proposed ASAT v18 because they exhibited good item infit. The respondent separation (2.55) and respondent reliability (0.87) scores for the proposed ASAT v18 indicated that it was sensitive enough to distinguish between high and low performing NHS trusts. The item separation (2.81) and item reliability (0.89) scores indicated that the sample was large enough to confirm item hierarchy.

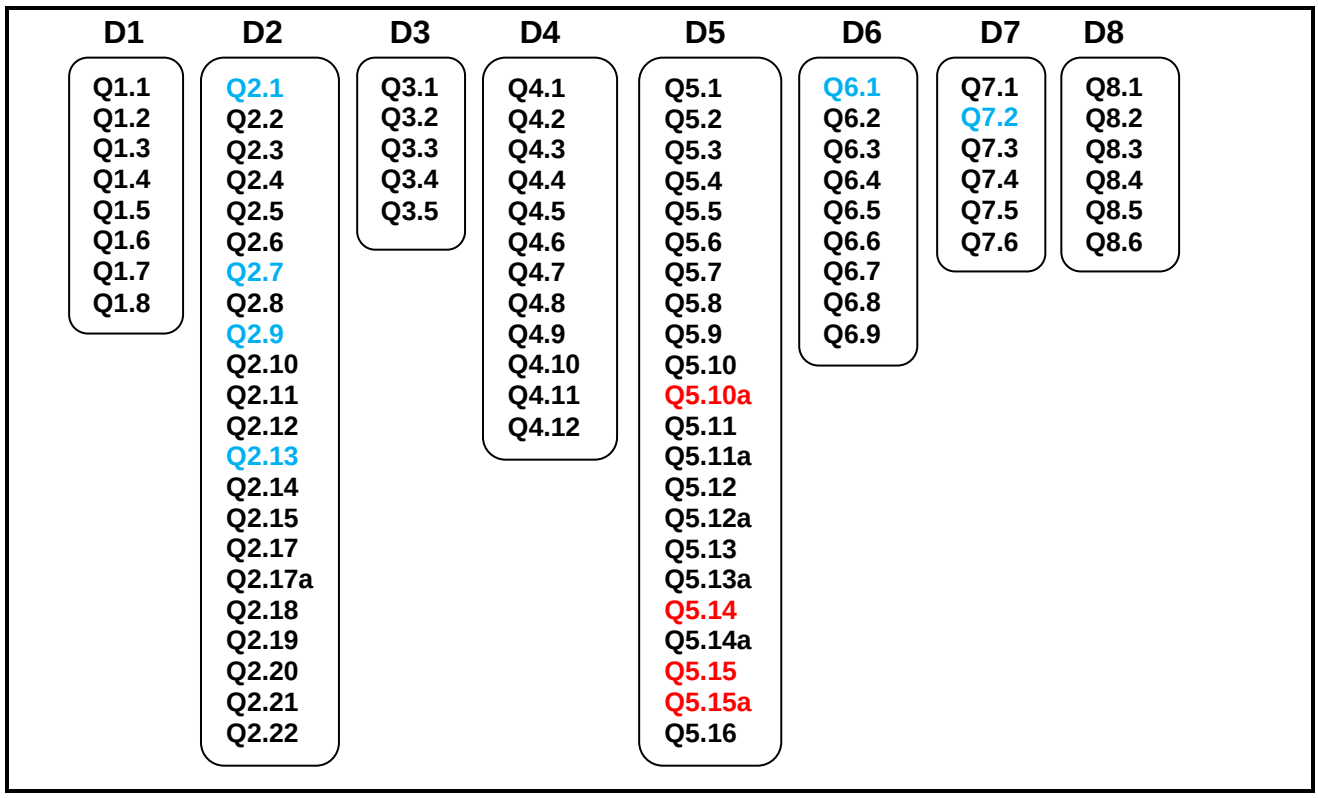

Figure 5.16 - The total item pool *(Domain 1-D1 to Domain 8-D8)* for Rasch modelling showing the *'dropped'* items (blue) and deleted items (red).
Nb. All other remaining items could be used to construct ASAT v18 (black) and these items categorised as productive for measurement by Rasch modelling. Items receiving perfect scores may be still be used to evaluate hospital-based ASPs however they may be unable to discriminate between NHS trusts.

The item/respondent map of the overall ASAT *(see figure 5.17)* showed that there was a good normal distribution of respondents therefore these items had the ability to discriminate between NHS trusts in the study sample.

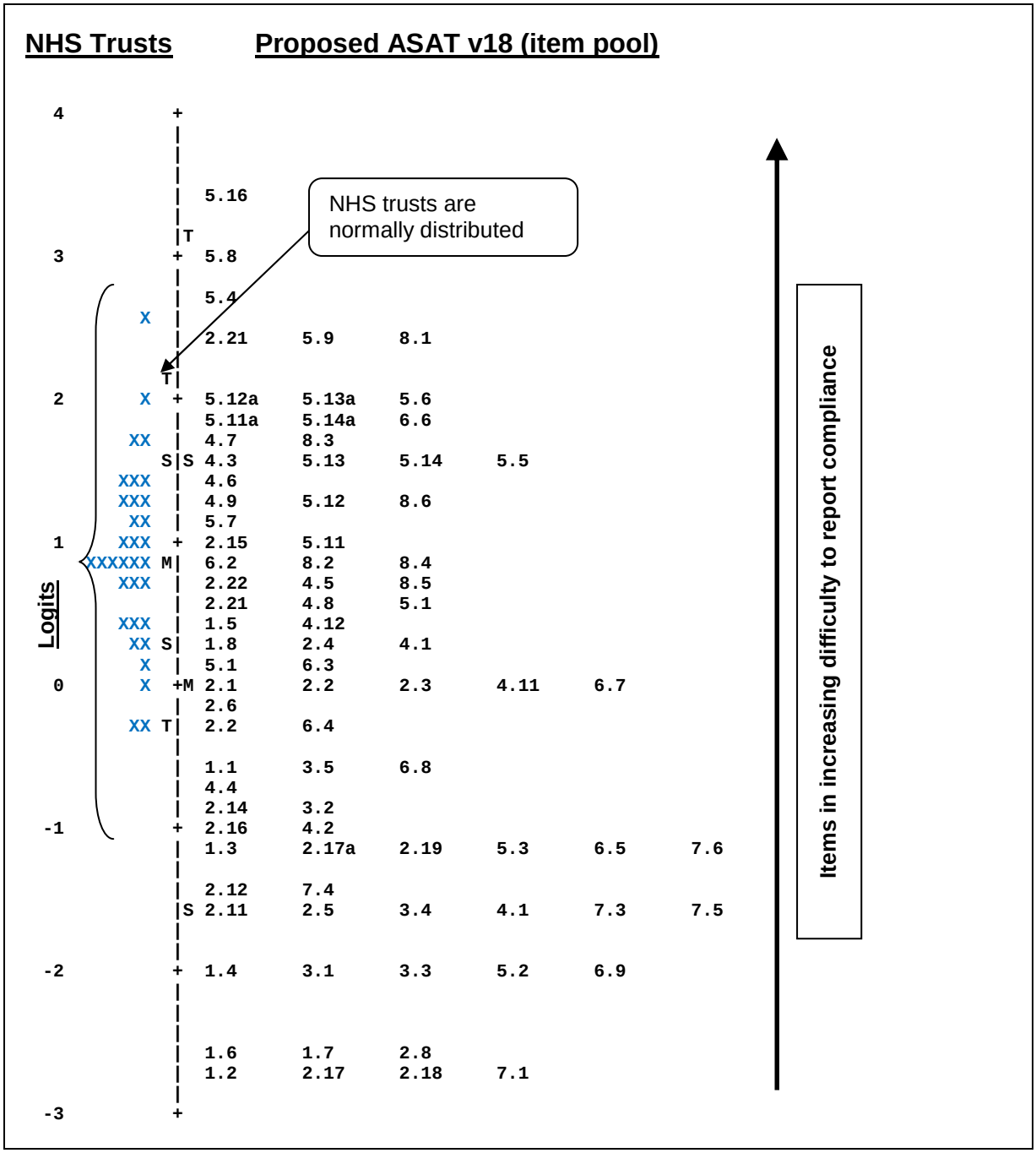

Figure 5.17- Respondents/items map (ASAT v18)

KEY:

M	Mean NHS trust or item distribution
S	One standard deviation from the NHS trust or item mean
T	Two standard deviations from the NHS trust or item mean
X	One NHS trust
#	Two NHS trusts

The NHS trusts exhibited a normal distribution which was indicative of good measurement. Item Q5.16, which asked if competency assessment was conducted for all antimicrobial prescribers, has the highest item discrimination in ASAT v18 as

this item was the most difficult to report compliance. Items Q1.2, Q2.17, Q2.18 and Q7.1 were the easiest items to report compliance by the study sample.

5.6 Discussion

This study was a novel approach to testing the validity an organisational questionnaire such as the ASAT so therefore there was very limited evidence to compare the findings of this study. There was only one study which looked at using Rasch analysis to investigate the validity of an organisational assessment instrument.[335] The instrument under investigation was a 231 item questionnaire with five domains which included domains such as management responsibility and resource management. However, the instrument used Likert scales and a Rating Scale model was used instead of a PCM. Consequently, it was difficult to interpret their findings using a Rating Scale analysis in light of the findings using a PCM. Chapter 5 presents the findings from the investigation of construct validity using Rasch modelling which was conducted on ASAT v17. The implications of the findings of this study are discussed in this section of the chapter. Rasch modelling was an effective diagnostic method at investigating the assumption of unidimensionality and item discrimination hence, construct validity of ASAT v17 at a sub-scale (ASAT domain) level *(section 5.5.1 to section 5.5.8)* and also at a scale (ASAT) level *(see section 5.5.9)*.

Firstly, at a sub-scale level, Rasch modelling identified items which were either overfitting or underfitting the model. These items had an INFIT MNSQ outside the range of 0.7 to 1.3 and hence did not fulfil the assumption of unidimensionality. Although there was item misfit detected at the sub-scale level in ASAT v17, the analysis demonstrated that each domain possessed items fulfilled the assumption of unidimensionality to their INFIT MNSQ values. However, the assumption of item discrimination was not fulfilled in each domain due to presence either ceiling or floor effects. Items which were underfitting the model were problematic because these items were potentially measuring variables external to ASPs. Items which were overfitting the model were not as problematic to the model because these items did not introduce noise into the model. Therefore, emphasis was placed on the examination of item fit after the removal of underfitting items. Generally, the removal of items improved the item fit to the PCM however it was observed that the removal of items Q1.3 and Q1.4 in domain resulted in multidimensionality being exhibited

within that domain. Qualitative evidence derived from the cognitive modelling studies conducted as part of this programme of work was used to provide possible explanations for item misfit. Most items that were underfitting the model were mainly as result of respondents' inability to collate the data required to answer the questions and also comprehension or interpretation problems.

On examination of the respondent/item maps for each domain, it was observed that there were ceiling effects in domains 1, 3 and 7 and a floor effect in domain 8. The ceiling effects were caused by the items being easy to report compliance by NHS trusts. Therefore, these domains had limited ability to discriminate between NHS trusts. A possible solution to improving the discrimination of these domains would be to include additional questions which examine the processes related to these domains more comprehensively. The floor effect was caused by items within domain 8 being difficult to report compliance. Domain 8 also has limited ability to discriminate between the NHS trusts within the study sample.

Table 5.33 -The process of development, testing and item reduction for ASAT v15a to ASAT v18[3]

Study type	Method	ASAT version	New[1]	Retained	Modified	Deleted	Total
Qualitative	**ASAT construction** Consensus expert review and literature review (ARHAI)	**15a**	83	n/a	n/a	n/a	83
Qualitative (Study 1)	**Content validity** Cognitive interviews with antimicrobial pharmacists	**16**	2	25	58	4	85
Qualitative (Study 2)	**Content validity** Cognitive interviews and semi-structured interviews with clinical microbiologists	**17**	5	85	1	0	91
Quantitative (Study 3)	**Construct validity** Rasch modelling and item categorisation	**18**	0	91	0		91
Productive for measurement		INFIT MNSQ between 0.7 to 1.3 **(n=81)**					
Unproductive for measurement		Perfectly scored items (n=6) and underfitting items **(n=4)**[2]					

[3] *New' represents questions that were developed from newly constructed questions including question merging. 'Retained' represents questions that remain unchanged. 'Modified' represents questions that were altered for example by conducting word insertions and word deletions*

[4] *These items were identified as underfitting the model however they may be informative for evaluation of ASPs because there may be useful in determining local practices but not for benchmarking purposes.*

Therefore, in order to improve the discriminatory ability of this domain, the items related to patient information about antimicrobial chemotherapy targeted by this domain could be reduced; for example, items that focus on patient information or documentation during the inpatient stay only. The analysis of the item fit of the overall ASAT v17 indicated that there were there were only three items that appeared to be underfitting the Rasch model. These items were sequentially removed from the analysis and the fit statistics were re-examined. It was found that the removal of these items resulted in the underfit on Q5.15a.

The analyses of the entire item pool of ASAT v17 identified that there were items which were productive for measurement and those which were unproductive for measurement *(see figure 5.16)*. The items which were unproductive for measurement included items which were perfectly scored by respondents, that is, Q2.1, Q2.7, Q2.9, Q2.13, Q6.1 and Q7.2. Also, there were items which were underfitting the PCM Q5.10a, Q5.14, Q5.15 and Q5.15a. These items may be useful in the ASAT to confirm that some AMS-related practices are in place although they lack the ability to discriminate between NHS trusts. The remainder of items were productive for measurement, that is, they would be able to discriminate between high performing and low performing NHS trusts. These items also fulfilled the assumption of unidimensionality as they had an INFIT MNSQ within the range of 0.7 to 1.3.

The ASAT was initially designed as a method of self-assessment which NHS trusts can use to evaluate their local ASPs. Consequently, based on these analyses, it was decided that within the next iteration of the ASAT (ASAT v18 - *Appendix XXVII*), it will clearly specify which items can be used for benchmarking purposes, that is, ASAT items that fulfil the assumptions of unidimensionality and item discrimination. Other modifications were made to ASAT v17 and included updates to the introduction of the ASAT, the inclusion of *'do not know'* or *'data not available'* to response options and also the inclusion of RAG status for ASAT scores. These modifications were made to ASAT v17 in order to produce ASAT v18 *(see Appendix XXVII).*

5.6.1 Potential limitations of Study 3

There are a number of limitations associated with this study. One limitation is that Rasch modelling focuses on detecting items which are productive for measurement and these items will have the ability to discriminate between respondents to identify *'high'* and *'low'* performing respondents. However, the purpose of the ASAT is to examine local implementation strategies for ASPs. Currently, it was not designed to be used as a benchmarking toolkit for comparative analysis of the performance of NHS trusts. As previously discussed, constructing a measure which is composed of items which possess the ability to discriminate between NHS trusts may be useful if the ASAT becomes a benchmarking tool in the future.

Rasch modelling was unable to produce estimates for items which have been perfectly scored either negatively or positively by respondents because of the probabilistic nature of the model. However, these items may target processes which are pivotal to implementing effective hospital-based ASPs. Consequently, they may be retained in the toolkit because of their importance to implementing ASPs however as previously it was denoted in ASAT v18 that these items were deemed unproductive for measurement due to the results of the Rasch modelling.

Another limitation of this study is that the response weighting previously allocated to the ASAT was not investigated by conducting Rasch modelling. The item hierarchy that is *'easy items'* and *'difficult items'* was investigated by Rasch modelling which was based on the ASAT responses provided by the participating NHS trusts. The respondent/item maps showed the item hierarchy at a sub-scale and a scale level. Therefore, further investigation is required to determine the most appropriate weightings for the response options in the ASAT in order to ensure the each question is correctly prioritised according to its efficacy on hospital-based ASPs. The item hierarchy compromised the results of the OLS regression modelling conducted in the next study was based on the NHS trust ability measures produced from Rasch modelling and the CDI rates for participating NHS trusts. However, poor correlations were observed at both sub-scale and scale levels which could potentially be due to the item hierarchy being based on NHS ability and not on previously assigned ASAT weightings.

Another limitation of this study is that it may be subject to sampling bias.[336] Participants were recruited via antimicrobial prescribing groups across England and the majority of NHS trusts (25/33) were from the North West SHA. Therefore, NHS trusts which were not members of antimicrobial prescribing groups were not recruited into the study.

One of the main limitations of this study is associated with the sample size used. The sample size was 33 out of the 167 NHS trusts, which equated to approximately 20% of NHS trusts in England. The proposed minimum sample size required for Rasch analysis is 30 respondents.[230] However, there are limitations associated with using a small sample size. The principle aim of this type of statistical analysis is to ensure that the sample size is sufficient to provide useful item calibrations which subsequently provide a useful level of measurement stability.[337] Small sample sizes could produce less precise estimates hence larger standard errors and also imprecise estimates of fit.[337] Recently, there have been investigations conducted into the effect of smaller sample sizes on the precision of mean square fit statistics in PCM using polytomous data.[338] They concluded that sample size invariance may exist for mean square fit statistics and also that larger sample sizes would increase the stability of Rasch models.

There have been a number of standards or guidelines for the acceptable item mean square ranges for infit and outfit statistics. However, these ranges are not standardised therefore the researcher has to conduct discretionary item deletion or retention dependent on the type of questionnaire or survey being validated. Another limitation of this work was that there was no definitive guidance for deciding item fit. Numerous ranges for fit indices have been proposed which are generally between the range of 0.4 to 1.7. Items with fit statistics within this range have been considered productive for measurement.[230] A more restrictive range has been proposed where 0.5 to 1.5 is productive for measurement. Values exceeding 1.5 are considered to be unproductive for measurement however these items would not degrade the overall measure. Values exceeding 2.0 are considered to degrade and distort the measure and introduce off-variable noise into the measure.[306] However, proponents of Rasch measurement techniques have suggested that researchers

should base their decisions to delete or retain items on evidence from the literature and also qualitative judgement in conjunction with the results for Rasch modelling.[274]

Another limitation of this work was that respondents who responded at the extremes on a measure that is responded either *'yes'* or *'no'* to all questions were not scalable by the PCM and subsequently their responses were not utilised in the calibration of the ASAT domains. For example, a total of 6 items receiving perfect scores were *'dropped'* from the analysis in domains 2, 5, 6 and 7. Interestingly, these questions related to the availability, frequency of review, content and also the staff groups involved in the development of antimicrobial guidelines. Responses to these questions were excluded from the calibration of the ASAT which relate to a fundamental intervention for improving ASPs.

The ASAT is a self-report measure which aimed to evaluate factual data on ASPs from NHS trusts. The use of questionnaires and surveys facilitates statistical analyses by providing standardised responses. Self-report questionnaires eliminate the possibility of interviewer bias. However, there are limitations associated with utilising questionnaires or surveys such as the ASAT to collect data. This method of data collection is limited due to the reliability on respondents to report data accurately.

- Forced choice (questions) response options therefore respondents may choose response options that are closest to their answer but are not necessarily accurate
- Inability to detect each respondent's interpretation of questions therefore respondents answer questions as a result of their own interpretation

Due to the nature of self-report measures the researcher could not validate the data obtained from respondents. These data were secondary data where responses were collated by the respondents and subsequently submitted to the researcher. Consequently, the researcher was unable to authenticate the accuracy or validity of these data.[339] One solution which could be used to overcome this limitation is the use of external peer review or internal validation to ensure that the responses to the ASAT were accurate and valid. An alternative approach would to use kappa inter-rater reliability scores to compare respondents with the same NHS organisation. Therefore, inter-observer variation could be measured by examining the kappa inter-

rate reliability score for two or more independent observers, where kappa = 1 (perfect agreement) and kappa = 0 (agreement due to chance observations).[340]

One of the key assumptions of Rasch modelling is that respondents answer items within the range of their *'ability'.* The PCM does not possess a guessing parameter, in other words, the PCM lacked the ability to detect guessing by respondents. In the previous studies conducted within this programme of work, respondents indicated that they may *'guess'* a response to a question within the ASAT and then may verify the answer(s) at a later date. The PCM was unable to detect guessing by respondents in Study 3. Some authors have proposed a guessing parameter or models such as Keats-White adjustments should be conducted in conjunction with Rasch modelling in order to account for guessing.[341] However, Keats-White adjustments reduce the precision of estimates produced by Rasch models so therefore these adjustments were not conducted. Alternatively, the inclusion of response options such as *'do not know'* or *'data not available'* would reduce the amount of guessing in response to ASAT items. Therefore, these options were incorporated into ASAT v18 in order to reduce guessing.

Another limitation of this study was conducted in NHS trusts in England because the ASAT was designed to be used in this type of healthcare organisation. Therefore, the generalisability of the study is limited to NHS trusts in the UK. Also, the extrapolation the results of this study to other hospitals outside of the UK would not be appropriate. Another limitation to the generalisability of these results is that the results may not be applicable to ASPs in outpatient or community care settings.

5.7 Conclusion

Rasch modelling and modelling provided was an effective diagnostic technique for guiding the development of the ASAT and hence provided evidence on the validity of the ASAT. The results further reinforced the need for defining the underlying trait (ASPs) and pretesting questionnaires for example using cognitive interviews prior to statistical modelling. Consequently, there was a justification for the utilisation the sequential exploratory strategy in this programme of work.

From the findings of this study, it can be seen that the Rasch modelling highlighted problematic questions in ASAT v17 which were supported by earlier findings in this programme of work. Items which were overfitting model were mainly due to question duplications which negatively impacted on the item discrimination of these questions hence overfitting the model. Underfitting items were mainly due to these items measuring external or other (non-related) systems to ASPs.

CHAPTER 6:

Simple OLS regression modelling of ASAT v18

6. INTRODUCTION

Chapter 5 presented the results of the quantitative study which investigated the construct validity of ASAT v17. That study represented the third stage of the sequential exploratory strategy used in this programme of work *(see section 2.1.3).* Chapter 5 also presented an overview of the findings of the Rasch modelling and modelling conducted on ASAT v17. The examination of the fit statistics was conducted at a sub-scale (domain) and also at a scale (ASAT) level. The findings indicated that at a sub-scale level there were items which were underfitting and overfitting the PCM. The items which were identified as misfitting the PCM were removed from the analysis and the fit statistics of the remaining items were re-analysed. In most instances, the results of these analyses showed that the removal of misfitting items did not significantly improve the stability of the PCM. Consequently, it was decided to retain these items in the dataset for further analysis. The next stage of analysis was to examine the overall fit of items in ASAT v17 in order to determine whether it was measuring a single underlying variable (latent trait) and also to determine which items were productive for measurement. The items which were found to be productive for measurement were used to further develop and improve the ASAT and hence construct ASAT v18.

Chapter 6 presents the results of the correlation analyses and simple OLS (bivariate) regression modelling *(see section 2.4.12)* conducted using the estimates or calibrations of NHS trust *'ability'* for ASAT v18. Bivariate regression modelling was conducted in order to describe and quantify the relationship, *if any*, between NHS trust *'ability'* (predictor variable) to implement ASPs and CDI rates (outcome variable). The trust apportioned CDI rates per 100 000 bed days were used in the simple OLS regression modelling. These data were publicly available and accessible via the Health Protection Agency's website. The time period of April 2011 to March 2012 was chosen because it corresponded with the time period used for the data collection for Study 3. Also, predictive validity of ASAT v18 was investigated using simple OLS regression modelling.

6.1 AIMS

- To investigate the ability of the validated measure (ASAT v18) to predict or model the *Clostridium difficile* rates of participating NHS trusts.

6.2 OBJECTIVES

- To investigate the magnitude and direction of the correlation between the predictor and outcome variables by calculating the correlation coefficient
- To determine the linear relationship (or approximately linear relationship) between the predictor (NHS trust *'ability'* estimates or calibrations) and outcome (CDI rates) variables by conducting simple (bivariate) linear regression modelling on each domain and the overall measure (ASAT v18)
- To examine the analysis of variance (ANOVA) of the regression model i.e. residual sum of squares (RSS)

6.3 METHODS

The NHS trust *'ability'* estimates (*βn*) *(see table 6.1)* were obtained from the Rasch modelling conducted in chapter 5 *(see section 5.4)* which provided estimates of the *'goodness of fit'* between item difficulty (*δi*) and respondent ability (*βn*).The values were reported in logits *(see section 2.4.11.2*) with two decimal places. If the score is extreme, a value was estimated, but as MAXIMUM (perfect score) or MINIMUM (zero score). The higher ability to respond favourably to ASAT items was represented by positive estimates and lower ability with negative estimates. NHS trusts with similar abilities produced similar estimates of calibrations. For example, in domain 8, 9/33 NHS trusts were estimates to have an ability of -3.26 due to the poor scoring for this domain, which were verified by the presence of a floor effect in the respondent/item map for domain 8.

It was decided to conduct the OLS regression analyses using a calibrated logit scale of estimates for NHS trust ability instead of unstandardised raw ASAT scores because it facilitated a standardised comparison between respondents and items.

As previously discussed *(see section 2.5.10)*, the NHS trust CDI rates *(see table 6.1)* were obtained from the HPA's website.

Table 6.1 - The NHS trust *'ability'* estimates from ASAT v18 and CDI rates for NHS trusts used in the correlation analyses and linear regression modelling

NHS trust	D1	D2	D3	D4	D5	D6	D7	D8	ASAT v18	CDI rates*
1	2.83	2.70	3.06	2.91	3.25	3.17	2.86	4.16	2.52	50.2
2	2.83	1.14	3.06	1.02	0.16	3.17	1.57	2.18	0.73	42.3
3	4.31	1.55	3.06	0.18	-1.09	0.92	2.86	1.44	0.82	17.1
4	0.75	0.72	0.46	0.61	-0.96	0.92	2.86	0.84	0.10	36.8
5	2.83	2.21	3.06	1.48	-0.04	1.91	2.86	0.62	1.10	52.2
6	4.31	1.80	3.06	0.61	1.70	3.17	2.86	0.33	1.94	33.7
7	4.25	-0.57	3.06	-0.12	-0.17	1.91	2.86	0.33	0.23	5.0
8	1.68	2.70	0.46	1.02	-0.17	5.00	2.86	0.33	1.29	71.1
9	1.68	2.70	3.06	-0.51	-0.96	1.91	0.66	-0.11	0.91	69.1
10	1.68	1.80	1.60	-0.12	-0.39	0.13	2.86	-0.11	0.47	48.4
11	2.83	3.83	1.60	1.48	-0.31	0.92	2.86	-0.38	1.29	39.5
12	-0.88	3.83	1.60	-2.08	-5.42	-0.57	1.22	-0.38	-0.05	39.3
13	4.31	2.06	0.46	-0.12	-1.43	-0.57	2.86	-0.38	0.65	33.3
14	1.68	1.80	3.06	-0.94	-0.96	0.13	1.57	-0.38	0.47	43.5
15	2.83	2.06	3.06	0.61	-0.17	0.13	2.86	-0.52	1.05	37.8
16	2.83	5.05	3.06	4.22	-1.43	-0.57	2.86	-0.52	1.19	36.2
17	4.31	1.80	3.06	1.02	-0.84	1.91	2.86	-0.52	0.43	50.9
18	4.31	1.35	3.06	2.05	0.55	1.91	2.86	-0.52	1.71	42.2
19	1.68	1.57	3.06	0.24	0.03	0.92	2.86	-0.52	0.96	47.4
20	4.31	3.16	3.06	0.61	-0.24	1.91	2.86	-0.52	0.91	51.2
21	4.31	1.80	3.06	-0.51	-0.31	1.91	2.86	-0.52	0.87	67.4
22	-0.88	3.16	1.60	0.24	0.09	1.91	2.86	-0.92	1.36	38.2
23	2.83	0.72	0.46	-0.94	-0.17	0.92	1.57	-1.35	0.76	51.9
24	2.83	1.80	3.06	1.02	-0.31	1.91	2.86	-1.88	0.84	42.4
25	2.07	-2.51	-0.50	-0.94	-0.96	0.92	0.00	-3.26	-0.33	19.3
26	2.83	0.93	0.46	-3.02	-0.55	0.13	0.66	-3.26	-0.25	52.1
27	4.31	1.80	2.73	1.82	-0.23	-0.57	2.86	-3.26	1.06	97.3
28	2.83	1.80	3.06	2.05	-0.10	3.17	2.86	-3.26	1.39	36.7
29	2.83	1.57	3.06	2.05	-0.47	5.00	2.86	-3.26	1.36	35.8
30	2.83	3.16	3.06	2.91	0.03	3.17	2.86	-3.26	1.68	32.8
31	2.07	1.33	3.06	-0.12	0.09	1.91	1.57	-3.26	0.92	42.1
32	1.68	1.57	0.46	-0.51	-1.43	-3.95	2.86	-3.26	0.31	54.8
33	2.83	2.35	3.06	4.22	-2.01	3.17	0.66	-3.26	1.25	51.8

**Nb. CDI rates were from the reporting period of April 2011 to March 2012*

The correlation and regression analyses were conducted in two stages. Firstly, each domain of ASAT v18 and subsequently, the overall ASAT v18 were analysed. These analyses were conducted in order to investigate if the validated measure (ASAT v18) can predict or model the *Clostridium difficile* rates of the participating NHS trusts. All analyses were conducted using SPSS v.20. These analyses were conducted using the CDI rates of NHS trusts as the outcome and also the NHS trust estimates as the predictor variable *(see table 6.1).*

Firstly, the correlation analyses were conducted and subsequently followed by the OLS linear (bivariate) regression modelling. The correlation analyses were conducted in order to determine the magnitude (strength) and direction of the

relationship (association) between the outcome and the predictor variables, which was determined by the correlation coefficient or Spearman's rank correlation coefficient (ρ). The range of ρ is between -1.00 and 1.00, where ρ =1 indicated a positive correlation and ρ = -1 indicated a negative correlation. The following guidelines were used to evaluate the size of the correlation between the two variables *(see table 6.2)*.

Table 6.2 - The ranges of correlation coefficients (ρ) and their interpretation. These ranges also applies to negative correlations[312;316]

Spearman's rank correlation (ρ)	Interpretation
0.0 - 0.2	Very low, practically zero
0.2 - 0.4	Low (minor) correlation
0.4 - 0.6	Moderate correlation
0.6 - 0.8	High correlation
0.8 - 1.0	Very high (almost perfect) correlation

Correlation analyses were conducted graphically using scatter plots of these data in order to examine the relationship between the outcome *(vertical axis)* and predictor *(horizontal axis)* variables. The regression analyses were conducted by plotting the regression line on the scatter plot produced from the relationships between the variables under investigation *(see section 2.5.11)*. The estimation of the regression parameters was derived from using the method of ordinary least squares (OLS). After the regression line was plotted on the scatterplot the residuals were identified using OLS regression. The residuals were observations associated with an error i.e. distance from the regression line. In order to investigate the predictive validity of the model, the regression equation for the model was calculated using *equation 4(see section 2.5.11)* from the coefficient outputs in SPSS. The analyses of the *'goodness of fit'* were conducted in order to investigate how well the model fits the data. These analyses were conducted by comparing the observed scores with the scores predicted by the model. The difference between the observed scores and the estimated scores are known as the residuals. Analyses of the residuals provided an indication of how well the model predicted each data point. Subsequently, the deviances were summed for all data points after there were squared to remove any negative values. The sum of all the squared residuals is known as the residual sum of squares (RSS). This stage of analyses provided a measure (indication) of how much the data deviates from the overall model (provides a measure of model fit).

6.4 RESULTS

The results of the correlation and regression analyses are presented at a sub-scale (domain) and at a scale level (ASAT v18).

6.4.1 DOMAIN 1 (Antimicrobial management with the trust)

The correlation coefficient *(ρ = 0.001)* indicated that there were a positive but very weak or no relationship between the variables *(see figure 6.1)*. This shows that very little or no correlation between the CDI rates and the NHS trusts *'ability'* estimates in domain 1.

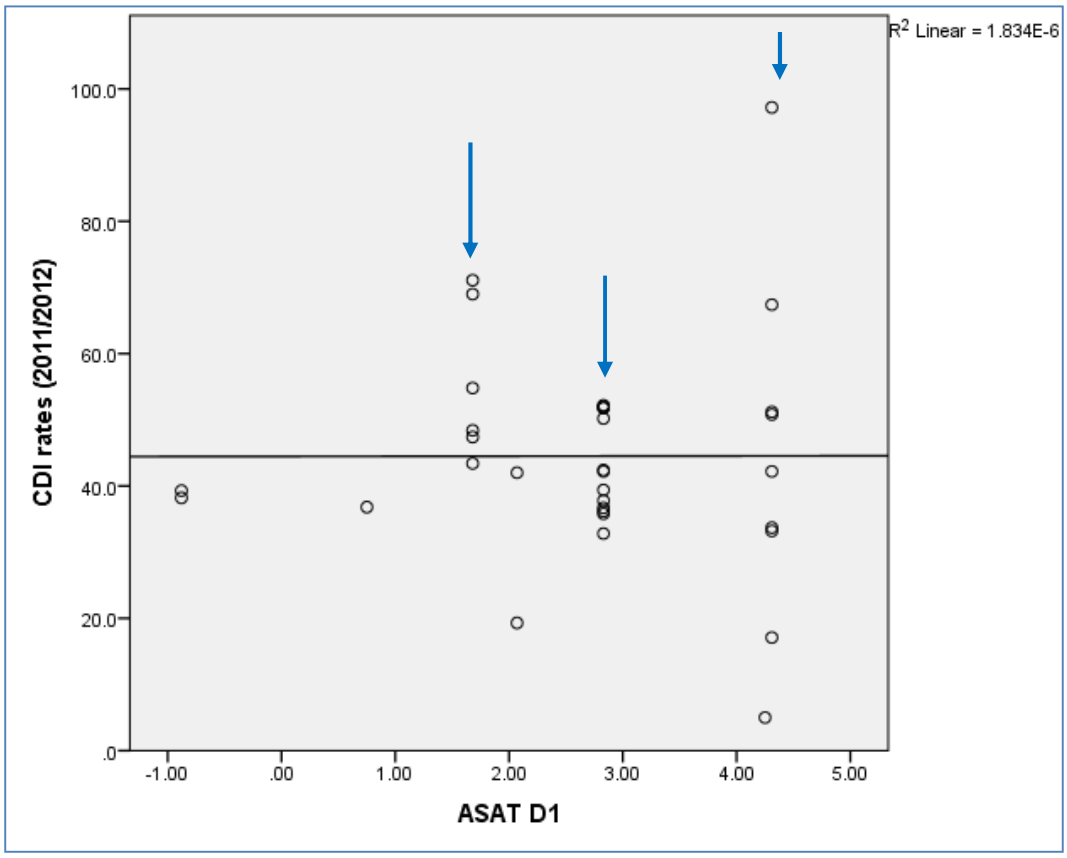

Figure 6.1 - Scatter plot illustrating the value of the correlation coefficient and the regression line for domain 1 (ASAT D1)

NHS trusts having the same estimates of *'ability'* were located at the same logit position along the x-axis as indicated by the blue arrows *(see figure 6.1)*. These estimates resulted in a ceiling effect for domain 1 *(see figure 5.1)*. This resulted in the very low, almost immeasurable) correlation between these two variables which was not statistically significant *(p=0.994)* because there was very little variation in the estimates for NHS trusts because most trusts achieved high scores for domain

1. This low correlation was confirmed by the regression modelling where the regression line is almost horizontal. Due to the nature of the regression it was decided not to conduct OLS regression (examination of residuals) on this model as it would not yield productive data as the R^2 value was 0. Hence, this domain had a very limited predictive validity. The regression equation for this model was [44.465 + (0.16 * x)]. The overall significance of the model was not statistically significant *(p=0.994)* which also indicated that predictor variables did not explain the variation in the outcome variable. As a consequence, extrapolating from this model was not recommended.

6.4.2 DOMAIN 2 (Operational delivery of the antimicrobial stewardship strategy)

The correlation coefficient *(ρ =0.280; p=0.11)* indicated that there was a very low (minor) positive correlation between the variables *(see figure 6.2)*.

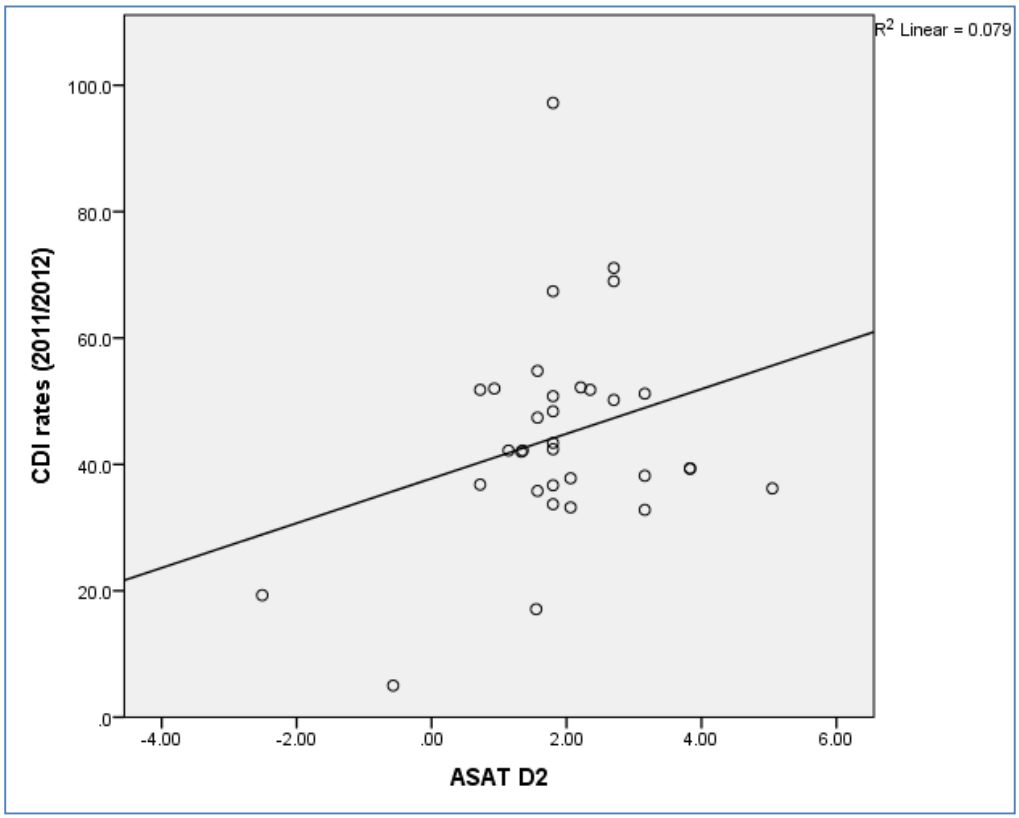

Figure 6.2 - Scatter plot illustrating the value of the correlation coefficient and the regression line for domain 2 (ASAT D2)

Most NHS trust estimates were positively skewed in the item/respondent map, where most trusts were located near to the higher estimates of ability produced by the Rasch modelling *(see table 6.1).* Consequently, this resulted in a limited

variation in the sample. The regression line indicated that there was a very low positive correlation between the *'ability'* estimates and the CDI rates. However, it was observed that the model only accounted for 7.9% *(R^2 =0.079)* of variation in the CDI rates of the participating NHS trusts.

6.4.3 DOMAIN 3 (Risk assessment for antimicrobial chemotherapy)

NHS trusts having the same estimates of *'ability'* were located at the same logit position along the x-axis as indicated by the blue arrows *(see figure 6.3)* There was little variation existed in the NHS trust estimates generated for the sample due to ceiling effects derived from responses to the items in this domain *(see figure 5.4)*. These ceiling effects were as a result of most NHS trusts located at the top of the operational range for this domain which subsequently affected the correlation analyses conducted on this domain.

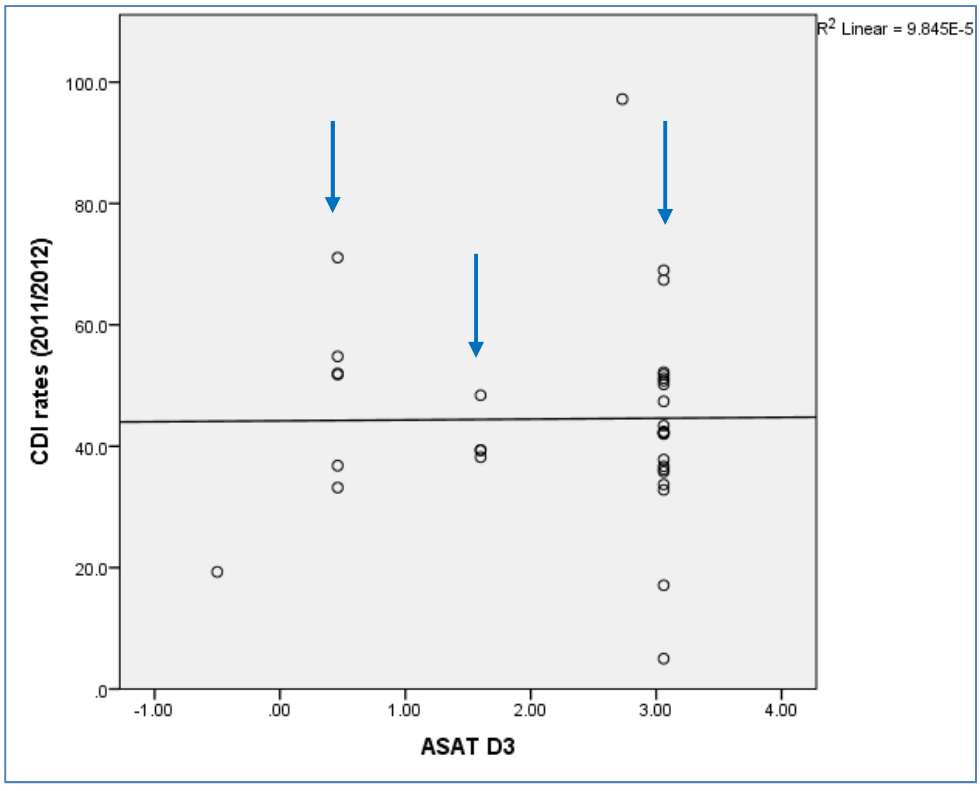

Figure 6.3- Scatter plot illustrating the value of the correlation coefficient and the regression line for domain 3.
Nb. NHS trusts having the same estimates of 'ability' were located at the same position along the x-axis and denoted by the blue arrows

Consequently, the correlation coefficient for this domain was almost negligible

(ρ =0.01; p=0.956) (see figure 6.3). Hence, the regression line showed that there was no demonstrable relationship between the two variables. The R^2 value was null *(R^2 = -0.03)* which indicated that this model could not account for the variation in the outcome variable. This was confirmed by the ANOVA analysis which showed that the F statistic was not statistically significant *(p=0.956)*.

6.4.4 DOMAIN 4 (Clinical Governance and Audit)

There was a very low negative correlation *(ρ =-0.151; p=0.403)* exhibited between the predictor and outcome variables for domain 4 *(see figure 6.4),* which was not statistically significant.

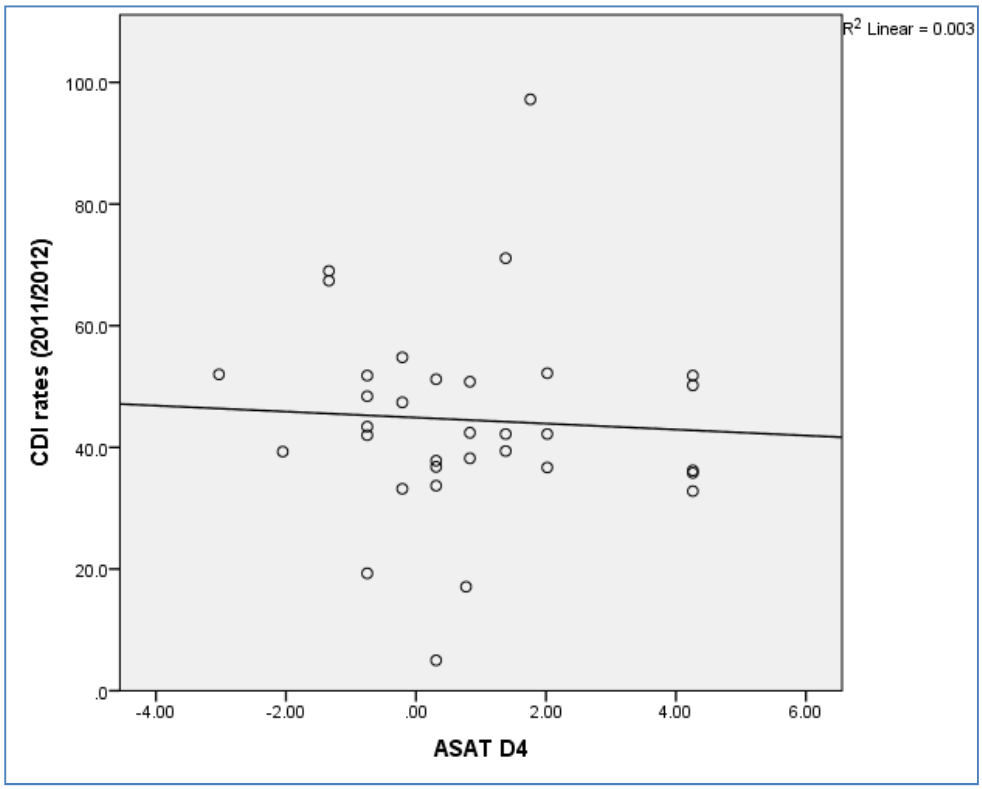

Figure 6.4 - Scatter plot illustrating the value of the correlation coefficient and the regression line for domain 4

This showed that the regression model for domain 4 lacked ability to predict the effect of clinical governance and audit interventions on CDI rates in NHS trusts. The regression analyses conducted on domain 4 indicated the model could only account for 0.3% variation *(R^2= 0.003)* in the outcome variable hence exhibiting low predictive validity. Again, this was confirmed form the analysis of variance where the F statistic *(p=0.824)* indicated that the regression model was unable to explain the variation in the CDI rates.

6.4.5 DOMAIN 5 (Education and Training)

Similarly to the other models produced for domain 2 and domain 4, there was a very weak association between the two variables under investigation *(figure 6.5)*. The NHS trust *'ability'* estimates for domain 5 showed that most trusts were located 0.00 and -2.00 with only two outliers.

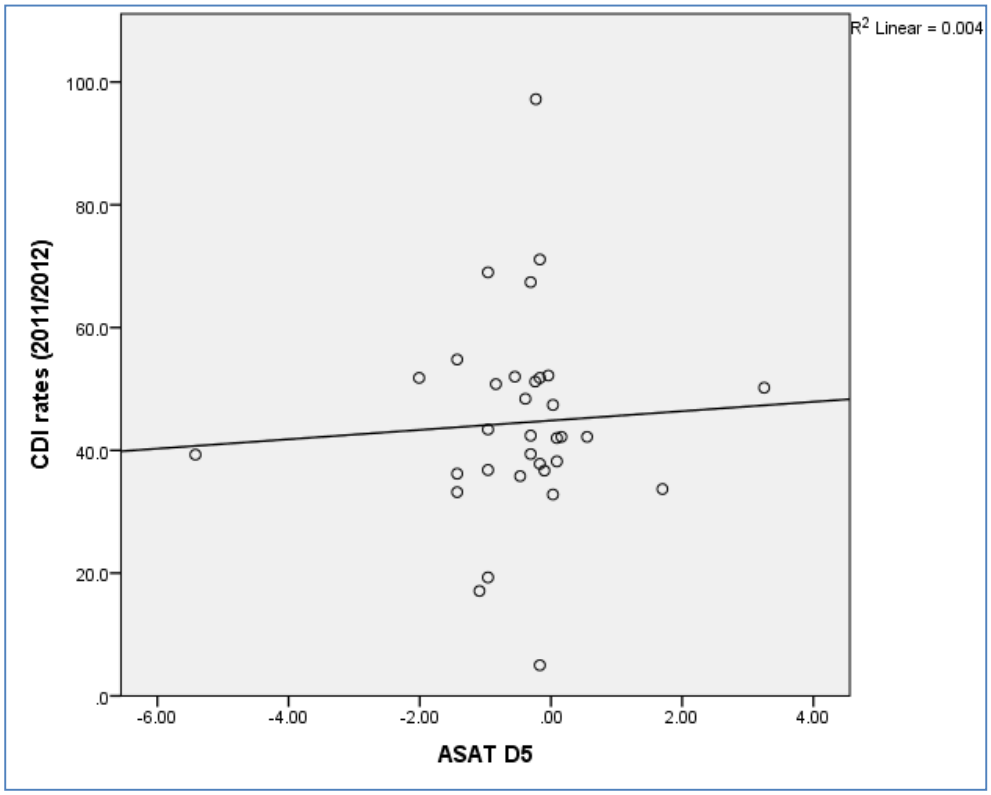

Figure 6.5 - Scatter plot illustrating the value of the correlation coefficient and the regression line for domain 5

This narrow distribution of NHS trust estimates negatively impacted on the correlation coefficient *(ρ = 0.059; p=0.744)* obtained for domain 5. The magnitude of the relationship between these two variables was very low. The model was only able to predict 4% of the variation in the outcome variable so therefore the predictive validity of the regression model was very small. Again, this was confirmed from the value of F statistic for this model *(F=0.109; p = 0.744).*

6.4.6 DOMAIN 6 (Antimicrobial Pharmacist)

The NHS trust ability estimates lacked variability and ranged from between -1.5 to 3.5 *(see table 6.1)*. As seen in other models were there was invariability of NHS trust estimates this resulted in very weak correlations being observed in the sample.

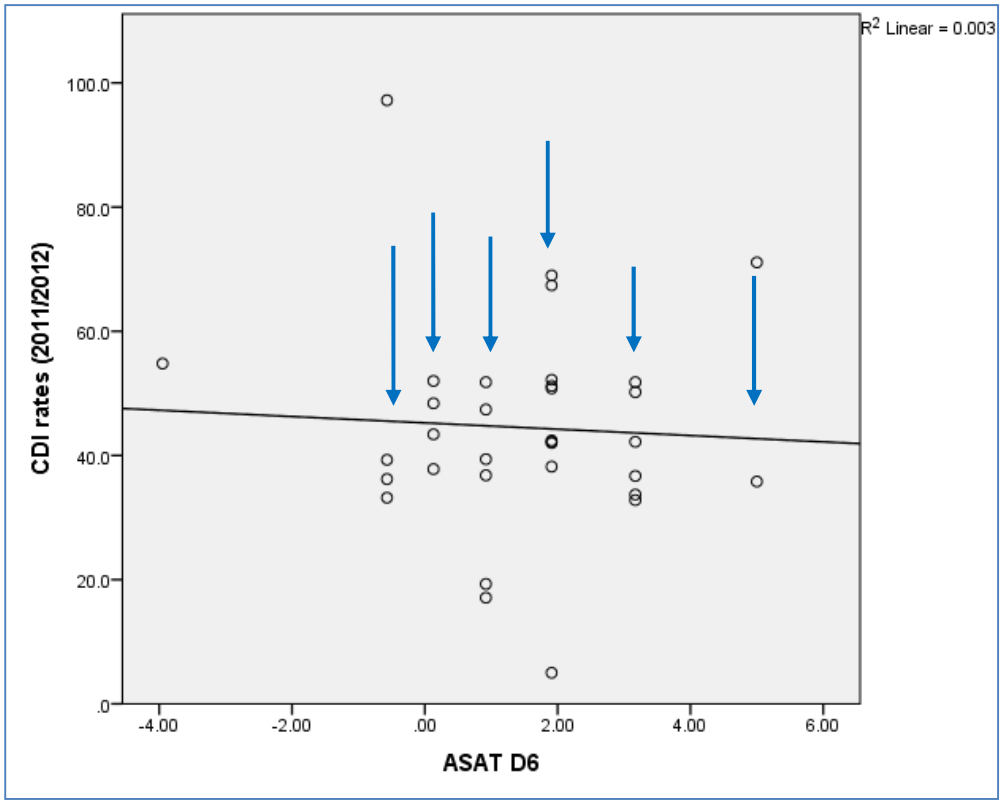

Figure 6.6 - Scatter plot illustrating the value of the correlation coefficient and the regression line for domain 6
Nb. NHS trusts having the same estimates of 'ability' were located at the same position along the x-axis and denoted by the blue arrows

The correlation coefficient for domain 6 indicated that there a very low negative correlation *(ρ = -0.054; p = 0.765)*. Consequently, the model was only able to account for 3% variation in the outcome variable hence limiting the predictive validity for domain 6. In other words, the model would be unable to predict the effect of antimicrobial pharmacists on CDI rates. Not surprisingly, this was confirmed by the F-statistic *(F=0.091; p =0.765)*.

6.4.7 DOMAIN 7 (Clinical Microbiologist)

NHS trusts having the same estimates of *'ability'* for domain 7 were located at the same logit position along the x-axis as indicated by the blue arrows (see figure 6.7). For domain 7, there was a lack of variability in NHS trusts estimates where 25/33 trusts had estimates between 2.5 and 3.0*(see table 6.1)* which equated to these trusts being located at the top of the operational range for this domain. Consequently, a ceiling effect was observed in domain 7 *(see figure 5.11)*, therefore the correlation analyses *(ρ = -0.16; p=0.928)* indicated that the relationship between variables was very weak however this correlation was not statistically significant.

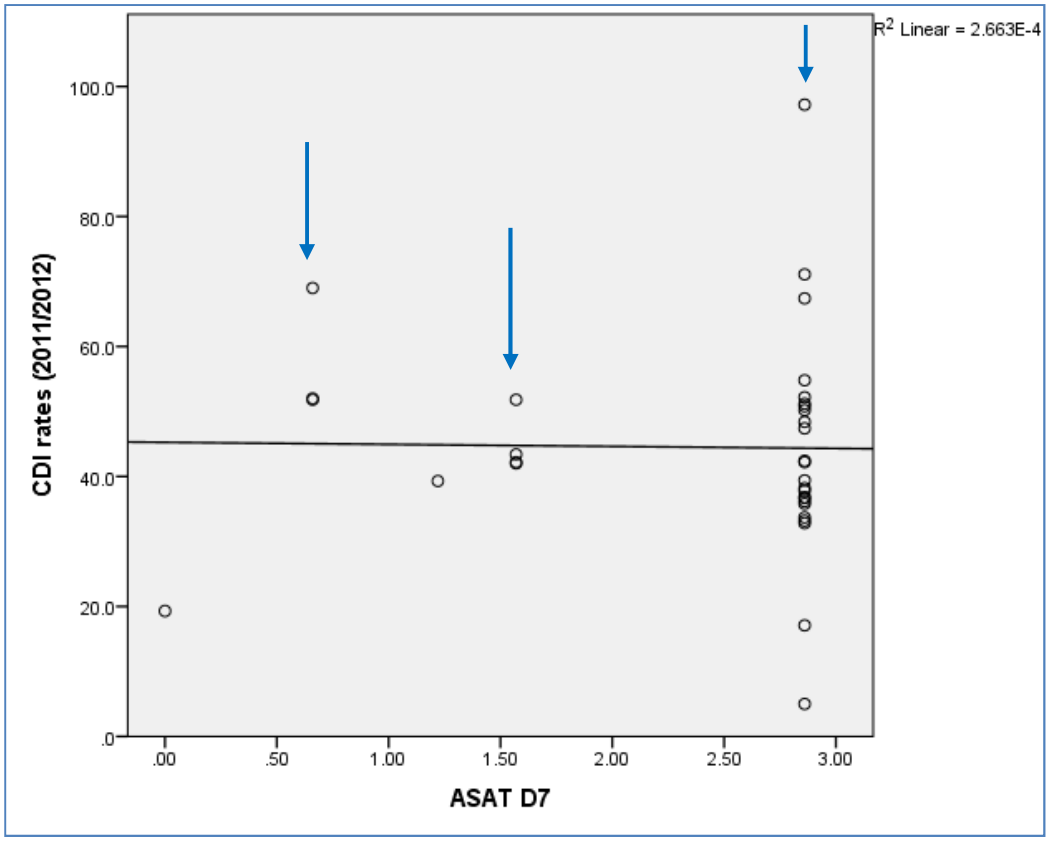

Figure 6.7 - Scatter plot illustrating the value of the correlation coefficient and the regression line for domain 7

This model was unable to account for any variation in the outcome variable *(R^2 = 0.00)*. Therefore, this model could not predict the effect of clinical microbiologists on CDI rates in NHS trusts hence limiting the predictive validity of the model.

6.4.8 DOMAIN 8 (Patients, Carers and the Public)

In study 3, it was observed that there was very little variability in NHS trust *'ability'* estimates produced from ASAT v18. Most trusts in the study sample generated ability estimates of -3.26 (n=9), -0.52 (n=8) and -0.38 (n=4). These low NHS trust

estimates were observed in the item/respondent map for domain 8, where there was a floor effect *(see figure 5.13)*. Consequently, this impacted on the correlation observed in domain 8 where the correlation coefficient *(ρ = -0.111; p=0.537)* indicated that there was a very weak negative association between the predictor and outcome variables *(see figure 6.8)*. In other words, the OLS regression analyses were unable to determine a relationship between the two variables due to the invariability of NHS trust estimates.

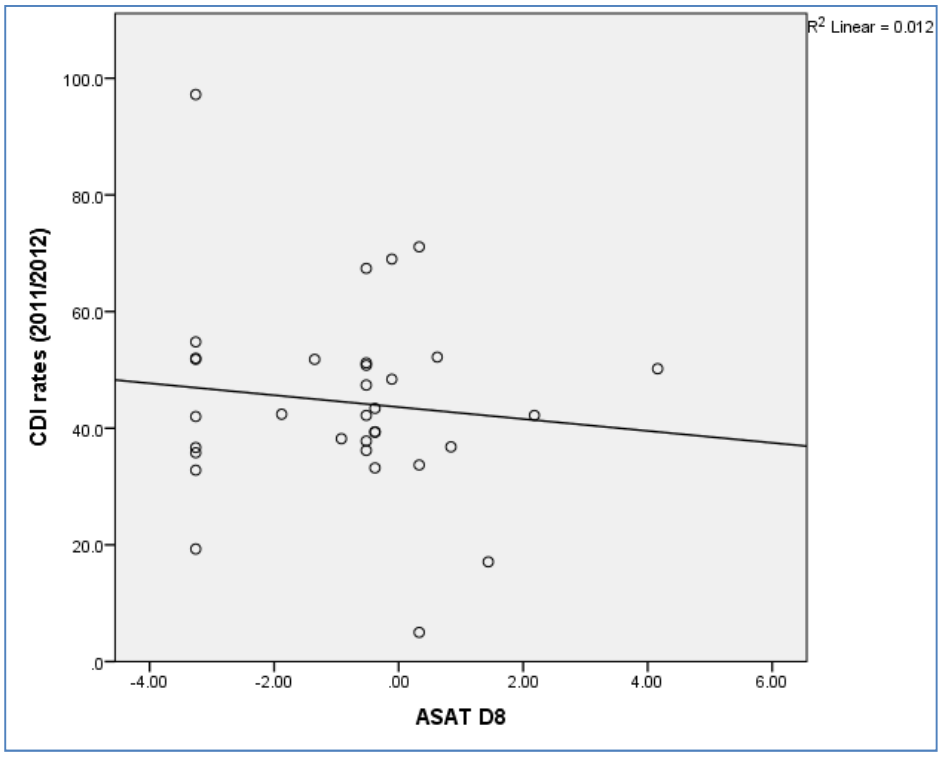

Figure 6.8 - Scatter plot illustrating the value of the correlation coefficient and the regression line for domain 8

The OLS regression analyses conducted on domain 8 indicated that the model could only account for 1.2% of variation *(R^2=0.012)* in the outcome variable. In other words, this model could not predict the effect of providing patients, carers and the public with information on the antimicrobials they have been prescribed on ASPs. This was confirmed by the F statistic *(F=0.389; p=0.537)*, because the significance of the F statistic is greater than 0.05, this indicated that the model was unable to explain or account for the variation in the response variable. Conversely, if this value was less than 0.05 then this would indicate that the regression model was able to account for the variation in the response variable.

6.4.9 ASAT v18 (Productive for measurement)

The next stage of the analyses was to investigate the model fit of the item pool of ASAT v18 which was productive for measurement *(see section 5.5.11)*. The correlation coefficient indicated that there was a very small positive association between the NHS trust *'ability'* estimates and CDI rates for participating hospitals *(ρ =0.146; p=0.418)*. However, this correlation was not statistically significant.

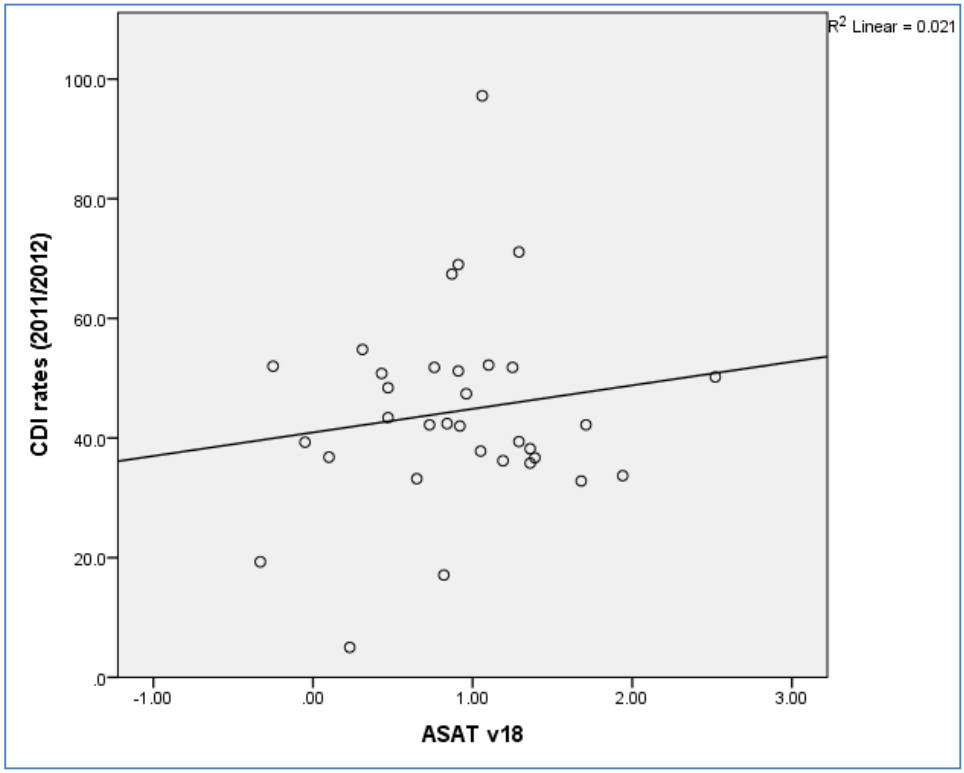

Figure 6.9 - Scatter plot illustrating the value of the correlation coefficient and the regression line for ASAT v18

The analyses indicated that this regression model had a very limited predictive validity. Subsequently, the model only accounted for 2.1% of variation (R^2 =0.021) in the outcome variable. In other words, the model could not predict the effect of cumulative interventions which are contained within ASAT v18 on ASPs. This finding was confirmed by the significance of the F statistic *(F= 0.674; p=0.418)* which was greater than 0.05.

6.5 Discussion

The correlation and regression analyses indicated that the regression models were either unable to account or possess very limited ability to account for the variation in the outcome variable (CDI rates). In most cases, the models were only able to account for less than 4% of the variation in the outcome variable. Also, on examination of the regression model for the proposed ASAT v18, it was clearly demonstrated that these models demonstrated limited predictability. There were a number of limitations associated with OLS regression modelling which may have affected the results obtained from the analyses.

Firstly, the ASAT was not designed to measure *'actual'* antimicrobial prescribing practices of NHS trusts such as route, dose etc. It was designed to evaluate the interventions used to NHS trusts to implement their ASPs. The ASAT evaluated each NHS trust's ASP but did not measure the quality of antimicrobial prescribing within participating NHS trusts. One of the hypotheses of the simple OLS regression analyses conducted in this study was that hospitals with good quality ASPs would prescribe antimicrobials better and hence have lower CDI rates than NHS trusts that did not have good quality ASPs. Subsequently, it would have been expected that these NHS trusts would have generate higher *'ability'* estimates than NHS trusts with poorer quality ASPs.

There were studies identified in the literature review conducted prior to the start of this programme of work used microbiological outcomes such as CDI rates, in order to determine the efficacy of their hospitals' interventions.[106;137;148;174;342] Therefore, guided by these findings, it was decided to utilise a microbiological outcome such as CDI rates as a good indicator of effective ASPs. However, the results of the simple OLS regression analyses indicated that microbiological outcomes such as CDI may not be the most appropriate indicator of effective ASPs. One explanation for these results was that the estimates generated for each NHS trust was based on their ability to endorse or report compliance to the questions within the ASAT. In other words, the responses to the ASAT indicated whether these NHS trusts utilised or did not utilise the methods of implementation evaluated by the ASAT. However, the ASAT did not measure whether NHS trusts were actively utilising these methods of implementation. For example, a NHS trust could report that it has a DIPC that had AMS as part of their job description. However, the DIPC may not be actively involved

in the NHS trust's ASP and therefore not significantly impacting on antimicrobial prescribing.

Point prevalence studies and/or other audits of antimicrobial prescribing which examine compliance to antimicrobial treatment and prophylaxis guidelines would generate data on the quality of antimicrobial prescribing. An approach which examined the prescribing practices associated with specific disease conditions and/or specific antimicrobials may have been more informative as an indicator of good ASPs as the dependent variable. However, these NHS trust-specific data were unavailable at the time of the study.

One of the main assumptions of OLS regression is that there is a linear relationship between the predictor variable (NHS trust *'ability'* estimates) and the outcome variable (CDI rates). These NHS trust *'ability'* estimates were derived from the Rasch modelling conducted in study 3. These estimates were indicative of the participating NHS trusts' ability to report compliance to the items in ASAT v18. The outcome variable was the CDI rates for the participating NHS trusts. Therefore, the assumption of the OLS regression modelling conducted was that NHS trusts which possess higher estimates of ability would have lower CDI rates. It has been argued that these two variables maybe strongly related but not exhibit a linear relationship hence giving a low or undetectable correlation. [314;315]

The limitations due to the choice of outcome variable for this study also presented further limitations to these analyses. The development of CDI could be subjected to confounders such as underlying aetiology, LOS, duration of antimicrobial therapy and the administration of multiple antimicrobials.[57;58] Additionally, the reduction in CDI rates can occur in the absence of dedicated antimicrobial control programme or formulary changes. For example, one US study achieved a sustained control of nosocomial CDI (1.24 per 1000 patient days) post-intervention by utilising enhanced infection control measures such as deep cleaning of equipment and the equipment in areas which were occupied by CDI patients.[343] Such confounders could potentially negate the correlations between the outcome and predictor variable as demonstrated in Study 4. The limitation of utilising microbiological outcomes such as CDI and MRSA to examine the predictive validity of the ASAT was evident from the results of the linear regressions obtained. The development of CDI and MRSA could be due to exposure to antimicrobials and not necessarily due to poor prescribing

practice. Also, any healthcare- associated infection could be due to a number of risk factors such as infection control practices, case mix of patients.

Other indicators of effective ASPs may have been more suitable for the simple linear regression analyses. The adherence to evidence-based antimicrobial prescribing guidelines may have been a better outcome to examine the impact of ASPs such as point prevalence studies (PPS). However, these data were not available. PPS examine the compliance to guidelines by utilising prescribing specific data such as choice (appropriate for infection type), route, dose, duration and time of administration (surgical prophylaxis).[344-346] However, these data are collected for one day only and are not annual performance data.

Utilising longitudinal studies of CDI rates after the implementation of ASPs could potentially overcome the limitations of utilising cross-sectional CDI data. ASPs could take a significant amount of time to demonstrate a positive impact on nosocomial infection rates. Therefore, the examination of the relative reduction in CDI rates over time could be a more sensitive indicator of the effectiveness of ASPs.
ASAT scores from which NHS trust abilities were derived, were indicative of the implementation strategies utilised by NHS trusts to promote prudent antimicrobial prescribing but not the actual uptake of these strategies or interventions. Consequently, there were weak correlations observed between ASAT scores and CDI rates. Additionally, utilising an outcome measure which was subjected to intrinsic and extrinsic confounders such as infection control practices and hospital ecology was not the most appropriate for the regression analyses.

CHAPTER 7:

Overall discussion and conclusion

7. INTRODUCTION

The primary aim of this programme of work was to validate and improve the ASAT. This toolkit is in a questionnaire/survey format and could be potentially used by NHS acute trusts to evaluate and subsequently recommend strategies for improving their current ASPs, where necessary.

As discussed in section 2.1.3, the unified concept of construct validity of the ASAT was investigated in this programme of work. Messick 1988 stated that '*the heart if the unified view of validity is that appropriateness, meaningfulness and usefulness of score-based inferences are inseparable and that the unifying force is empirically grounded construct interpretation'.*

The approach undertaken in this programme of work has been an iterative validation and improvement of the ASAT and was conducted utilising a sequential exploratory strategy *(see figure 2.1)*. This was a four-phase sequential design which was composed of two qualitative phases (Study 1 and Study 2) and two quantitative phases (Study 3 and Study 4). This design was utilised in order to undertake a robust validity testing process for the ASAT *(see section 2.1.3)*. The results of study 1 to study 3 were used to modify and improve the ASAT. This chapter aims to discuss the key findings or results and also provides a summary from the overall programme of work.

7.1. Overview of chapters in the programme in work

Chapter 1 presented the rationale for undertaking this programme of work. Prior to conducting this programme of work, a systematic approach was used to evaluate and critique the current evidence on the organisational interventions used to implement hospital-based ASPs. The results of this literature review indicated that hospitals utilised several strategies for implementing ASPs such as audit with feedback *(see section 1.10.5.1)*, education of prescribers *(see section 1.10.5.2)* and antimicrobial guidelines *(see section 1.10.5.4)*. Restrictive, persuasive and structural interventions appeared to be efficacious in promoting ASPs. However, most interventions were multifaceted for example a restrictive intervention such as pre-approval may have a persuasive component such as audit with feedback. It was essential to conduct the review of evidence in order to ensure that ASAT v15a was comprised of the pertinent interventions for promoting judicious antimicrobial prescribing in hospitals. Consequently, it was decided that in order to further develop

the ASAT, studies would have to be designed in order to investigate and improve its validity. These validity studies would comprise this programme of work and utilised study populations which were representative of the intended end-users of the ASAT.

Chapter 2 presented the rationale for the methods chosen for this programme of work. Both qualitative and quantitative methodologies were incorporated into a sequential exploratory strategy *(see figure 2.1.3)*. Qualitative methods (cognitive and semi-structured interviews) were used to investigate the content validity of the ASAT. Quantitative methods (Rasch modelling and simple OLS regression modelling) were used to investigate the construct and predictive validity of the ASAT. The results from each validation study were used to modify and improve the ASAT and subsequently produce further iterations of the ASAT. Therefore, chapter 2 provided an overview of the methodologies utilised in this programme of work which subsequently resulted in the iterative development of ASAT v18 from ASAT v15a.

Chapter 3 presented the findings from Study 1 which focused on the investigation of the content validity of ASAT v15a was conducted utilising cognitive interviews with eight AMPs across the northwest SHA. These interviews represented the first phase of the sequential exploratory (qualitative) phase of this programme of work. The findings of Study 1 indicated that respondents encountered difficulties during the cognitive processing phases required to generate responses to the questions in ASAT v15a. Comprehension problems were the most commonly reported difficulty by respondents *(see section 3.6.1)*. Other findings indicated that ASAT v15a contained question duplications *(see section 3.10.1)*, double-barrelled questions *(see section 3.10.2)*, and irrelevant key concepts *(see section 3.10.3)*. Another important finding was that respondents queried the rationale underpinning the scores and weightings applied to some of the questions in ASAT v15a *(see section 3.10.4)*. Also, respondents indicated that a section which examined the roles and responsibilities of clinical microbiologists should be included in future iterations of the ASAT. The findings from Study 1 established that ASAT v15a possesses a degree of content validity however further modifications were required to improve its content validity. Furthermore, these findings were used to inform the development of ASAT v16 which primarily involved the resolutions of the cognitive problems reported by antimicrobial pharmacists.

Chapter 4 presented the findings from Study 2 which focused on the investigation of the content validity of ASAT v16 which conducted utilising cognitive interviews and semi-structured interviews conducted with ten clinical microbiologists. These interviews represented the second phase of the sequential exploratory (qualitative) phase used in this programme of work. These interviews were conducted in order to investigate the content validity of ASAT v16 and also to determine whether the domain specifically evaluating the role of clinical microbiologists should be included within the next iteration of the ASAT, that is, ASAT v17. The results of this study indicated that the clinical microbiologists generally agreed with the content of ASAT v16. However, they suggested that a section specifically measuring and evaluating their roles in ASPs was necessary in future iterations of the ASAT. They indicated that this domain was essential because they have a leadership role in hospital-based ASPs. Study 2 appeared to be confirmatory in nature because there were issues raised by both groups of healthcare professionals regarding the ASAT and also hospital-based ASPs. For example, comprehension problems were the most commonly reported problem by clinical microbiologists *(see section 4.5.11)*. Problematic terms included *'antimicrobial formulary'*, *'antimicrobial guidelines'* and *'antimicrobial stewardship committee'*. The findings of this study were used to modify and improve ASAT v16 and in order to improve its content validity. One of the main modifications to ASAT v16 was the inclusion of the domain that evaluates the roles and responsibilities of clinical microbiologists so that the ASAT targeted the relevant areas of ASPs as indicated by the respondents.

Chapter 5 presented the results of the Rasch modelling conducted on ASAT v17 using the PCM. These statistical analyses were conducted in order to investigate the construct validity of ASAT v17 and ASAT v18. These analyses represented the third phase of the sequential exploratory (quantitative) phase of this programme of work. The results of the analyses conducted on ASAT v17 indicated that there were misfitting items (overfitting or underfitting) within each sub-scale (domain). Further analyses conducted after the removal of misfitting items indicated that their removal did not significantly destabilise the INFIT MNSQ statistics of the sub-scales in most cases. The analysis of the fit statistics of the overall measure (ASAT v17) indicated that the ASAT appeared to be measuring the underlying trait under investigation that is, organisational interventions to promote AMS. There were two types of items

identified from the analysis of ASAT v17 and there were either productive or unproductive for measurement. The items which were productive for measurement had INFIT MNSQ statistics within the range of 0.7 to 1.3. The items with INFIT MNSQ statistics outside of this range were either redundant or potentially measured an external variable. Items which received perfect scores lacked the ability to discriminate between NHS trusts because it was difficult to estimate their difficulty. Consequently, it was decided that ASAT v18 will include items which were productive for measurement and those which were unproductive for measurement. The items which were productive for measurement were highlighted in ASAT v18, so that they could be used for benchmarking purposes or comparative analyses, if required. Therefore, facilitating both self-assessment and benchmarking by end-users, were appropriate.

Rasch modelling utilising the PCM was an effective diagnostic statistical technique for evaluating the construct validity of the ASAT. These analyses provided evidence for the construct validity of the ASAT by the investigation of the unidimensionality of each sub-domain and the overall ASAT. The findings of this study identified items which were unproductive and productive for measurement. Also, the findings were used to generate recommendations for further iterations for improving the ASAT. For example, items which were unproductive for measurement such as those receiving perfect scores maybe useful for evaluative purposes. In other words, these items would be useful for the self-assessment of organisational performance (factual) data.

Chapter 6 presented the findings of the simple OLS regression modelling conducted on ASAT v18. These analyses were conducted in order to investigate the predictive validity of the ASAT v18. The results of these analyses indicated that ASAT v18 had limited predictability due to very weak (positive or negative) correlations observed between the dependent (CDI rates) and the independent variable (NHS trust *'ability'* estimates). In most instances, the ASAT could only account for approximately less than 5% of the variation observed in the dependent variable (CDI rates). This could be primarily due the lack of causal relationship between the two variables under investigation and also the invariability in the NHS trust estimates produced from the Rasch analyses in Study 3. Additionally, NHS trusts could have high estimates of *'ability'* however this estimate was not indicative or provided evidence of the quality of the NHS trusts' antimicrobial prescribing practices. The incidence of CDI was used

as a microbiological indicator of antimicrobial prescribing practices therefore OLS regression analyses. It may have been more informative to utilise a variable(s) such as compliance to antimicrobial treatment or surgical prophylaxis guidelines. However, these data were not available.

7.2. Overall strengths of programme of work

As previously discussed in *section 2.1.3*, a sequential exploratory strategy *(see figure 2.1)* was used to investigate and improve the validity of the ASAT. This approach utilised both qualitative and quantitative methods which is also known as mixed methods for data collection and analyses. One of the key strengths of using this approach was it compensated for limitations associated with a unimode approach. Furthermore, this sequential approach facilitated data triangulation for example the verbal reports from Study 1 and 2 were used to propose potential reasons for item underfit or overfit in Study 3. [222]

Rasch modelling has traditionally been used in the field of educational research to develop tests for students in secondary and post-secondary institutions. This was first study to utilise this type of statistical analyses on a hospital-based self-assessment instrument. Rasch modelling was used to investigate the construct validity of the ASAT. However, this statistical method also identified items which are productive and unproductive for measurement. Also, the researcher is able to observe the hierarchy of items at a sub-scale and scale level in other words, which items were easy or difficult to endorse by NHS trusts. Therefore, in the future, if the ASAT was used to conduct comparative analyses between NHS trusts, those items which are productive for discriminating between NHS trusts have been identified by these analyses.

7.3. Overall limitations of programme of work

There were a number of limitations associated with this programme of work and these have been previously discussed in preceding chapters. For example, Study 1 was undertaken within the Northwest SHA only, which represented one out ten SHAs across England. Also, there were 29 NHS trusts in the Northwest SHA at the time of Study 1 and only 27.6% of these trusts took part in Study 1 and therefore limits the generalisability of Study 1. Also, in Study 1, the cognitive interviews were

conducted until saturation was reached. It has been recommended that researchers should assess saturation after five to eight interviews, for example Patrick and his colleagues state,

'To assess saturation, transcripts and coding can be evaluated after a set of five to eight interview or focus group transcripts become available.' [347]

The researcher followed this approach to assessing saturation and observed that saturation was reached after interview 5. The verbal reports generated from these participants may not be representative of the entire population of NHS trusts in England. Subsequently, the results from Study 1 should be interpreted with caution and care should be taken in generalising these findings to other NHS trust settings.

As previously discussed, a sequential exploratory strategy *(see section 2.1.3)* was undertaken in this programme of work, in order to validate and improve the ASAT. However, there are limitations associated with this approach in investigating the validity of the ASAT.

Firstly, the researcher had to make key decisions with regard to the findings of the qualitative phase of the strategy. This was important because the qualitative studies were conducted before to the quantitative component of the sequential exploratory strategy. Therefore, the key emergent themes identified from the thematic framework analyses were used to modify, improve and produce further iterations of the ASAT hence inform the quantitative phase of the strategy. The researcher endeavoured to limit researcher bias for example the researcher utilised previously developed models of cognitive processing that is, the Four-Stage model *(see section 2.2.10.5.1)* and the Flexible Processing model *(see section 2.2.10.5.2)* when analysing the cognitive interviews.

Secondly, only cross-sectional data were collected from participating NHS trusts in this programme of work. This approach was used to obtain a *'snap-shot'* of the current status of hospital-based ASPs using the ASAT. Therefore, these data were only representative of the interventions used at the time the data were collected by the researcher. The interventions for implementing ASPs used by the participating NHS trusts may have changed since the data were collected by the researcher. Therefore, these types of data are unable to account for changes over time as with longitudinal studies. Consequently, the interpretation and the extrapolation from the findings from these studies to other settings should be conducted with caution.

Another limitation associated with this programme of work is that the CDI rates used in the simple OLS regression modelling was subject to reporting bias. There may be variations in the quality of data submissions to the HPA by NHS trusts. The CDI data submissions to the HPA may not be validated to ensure that there was good data quality. These CDI data were used for the OLS regression modelling in Study 3. Therefore, the reporting bias could potentially account for the weak associations observed in Study 3. As a result, reporting bias may have introduced confounders into the study.

Due to these limitations, consensus methods may have been more appropriate to use in order to evaluate and further develop the ASAT. Consensus methods can involve heterogeneous sample of respondents and are therefore viewed as being more robust method for indicator development. Therefore, in terms of the ASAT, members from each group of healthcare professionals involved in AMS could participate. Campbell and his colleagues[348]define consensus methods as '*structured facilitation techniques that explore the consensus among a group of experts by synthesising opinions'*. Examples of consensus methods include the Delphi technique and the RAND Appropriateness method. The Delphi technique has been used to develop prescribing indicators and can involve multiple rounds of questionnaires. There are a number of stages involved in this technique which include the definition a clinical problem and the development of draft indicators for rating by experts. These draft indicators would be scored or rated by a select group of panelists and the results would be fed back to between rounds. The RAND Appropriateness method involves some aspects of the Delphi technique and the nominal group methods. However, panelists are invited to discuss, review and rerate indicators after a face to face panel meeting.

7.4. Overview of the interpretation of results in light of published literature

A detailed interpretation of the results from Study 1 *(see section 3.6)*, Study 2 *(see section 4.5)*, Study 3 *(see section 5.5)* and also Study 4 *(see section 6.4)* has been presented in the previous chapters. Consequently, a brief summary of the interpretation of results will be discussed.

There were no published studies which investigated the use of cognitive interviews with AMPs to validate a questionnaire in the acute care setting. For example, there was one study which investigated the validity of a questionnaire using cognitive interviews with pharmacists.[349] However, this was conducted in primary care where cognitive interviews were used to validate an instrument which measured community pharmacists' self-efficacy beliefs about communicating with Spanish-speaking patients. Irwin and her colleagues used this method to validate patient-reported outcomes for paediatric patients.[332] Similar to the findings in Study 1, they found that comprehension problems was the most commonly reported cognitive difficulty reported by respondents. This difficulty was reported in both rounds of cognitive testing, which is also similar to the findings in Study 2.

There were no published studies which examined the perspectives of clinical microbiologists on ASPs in the hospital setting. One qualitative study looked at the influences on antimicrobial prescribing decisions for lower respiratory tract infection.[350] However, this study was conducted in primary care and only focused on the prescribing decision but not hospital ASPs. Semi-structured interviews were effective in providing data on the role of clinical microbiologists and also the challenges of developing ASPs in hospitals. These data confirmed that the ASAT was targeted the important components of ASPs.

In Study 3, Rasch modelling was used in the investigation the construct validity of ASAT v17 and ASAT v18. This method has not been previously used to investigate the construct validity of a questionnaire which assesses organisational implementation strategies for ASPs. As previously discussed *(see section 5.5)*, there was only one study found which used Rasch modelling to investigate the validity of an organisational questionnaire.[335] Saad and his colleagues investigated the validity of a questionnaire with five domains and 231 questions. The domains which comprised this questionnaire were management responsibility, resource management, product realisation, measurement improvement and realisation and also organisational performance. They indicated that Rasch modelling was an effective diagnostic method for identifying misfitting items which was similar to one of the findings of Study 3. However, they used Rating Scales instead of the PCM which

is only suitable for Likert type items so therefore it was not possible to compare further findings.

7.5. Implications for researchers

The sequential exploratory strategy undertaken in this programme of work utilised both qualitative and quantitative methods. These qualitative methods which incorporated cognitive and semi-structured interviews were effective at diagnosing and identifying the deficiencies in the wordology and phraseology of the ASAT. Also, these methods provided evidence of the validity of the ASAT. Additionally, there were three other advantages of utilising these qualitative approaches. Firstly, the verbal reports provided data on the current status of ASPs across the Northwest SHA from the perspectives of antimicrobial pharmacists and clinical microbiologists. Secondly, the verbal reports provided data on the usability of the ASAT in *'real world'* settings such as pharmacy departments. These data further elucidated the barriers and challenges respondents encountered with data collation. This enabled the researcher to ensure that the ASAT was designed intuitively and in a logical manner. Therefore, it was essential to utilise a target population which was similar to the intended end-users of the ASAT.

More robust methodology needs to be applied to studies on implementation methods for AMS. More specifically, in the investigation of the most informative outcomes that should be use to determine the efficacy of interventions. Outcome measures which are not potentially directly linked to an intervention could be indicative of change but should not be used to determine the efficacy of interventions. Ideally, you need to use outcomes measures that are directly linked to interventions. Outcome measures such as LOS, mortality, readmission rates are standard measures used to decide whether an intervention is efficacious or not. However, these outcome measures are subjected to multi-factorial influences which not be attributed to the interventions only. Outcomes should be directly linked or correlated to interventions. For example, the efficacy of a restrictive intervention such as pre-approval could be determined by examining the antimicrobial consumption rates of targeted antimicrobials however there are limitations associated with using this measure. In 2003, ARPAC conducted an observational cross-sectional study and invited each member of ESCMID to participate.[351] Also, ESCMID members were asked to provide their hospital antibiotic

policy and consumption data that related to 2001. Furthermore, the ARPAC study was conducted in order to investigate the relationship between six AMS indicators or factors and antimicrobial consumption data. The six factors which are also contained within the ASAT examined whether each hospital had an antimicrobial committee, a written antimicrobial policy, a written antimicrobial formulary, a formulary which included a restricted antimicrobial list, a DT&C and a strategic management goal of improving prescribing. However, they found that they were unable to identify any significant relationship between these key factors and total antimicrobial consumption. They suggested that this could be due to measurement bias, AMS factors or indicators which lacked sensitivity, the use of aggregated antimicrobial consumption data or failure to account for other potential confounding factors. Furthermore, they stated that qualitative reasons for antimicrobial usage were not considered in their study. These findings reinforce the need to identify more sensitive structure, process and outcome measures for the evaluation and improvement AMS-related interventions.

Economic evaluation or cost effectiveness analyses tend to report on the cost savings attributed to target antimicrobials. However, costs related to the implementation of ASPs and other should be considered in the cost analyses as well. There may be compensatory effects of interventions that are not considered in the analyses. These compensatory effects may include the (increased) usage of other antimicrobials with similar spectra of activity as the targeted antimicrobials, increased staff, training costs, increased staff hours and infrastructure such as computer and/or computer programs etc.

7.6. Implications for policy makers

This research found that there was a clear disparity between that ASAT developers' intent and the respondents' interpretation of the ASAT. There is an assumption that the end-users of targeted staff groups of guidelines would interpret them as the developers have intended. The primary disparities in this research were due to comprehension and interpretation of terminology. Although the ASAT is a single questionnaire, the results of the cognitive testing could potentially highlight that there is a need to address the interpretation of terms by healthcare professional prior to guideline publication and dissemination. Therefore, cognitive testing should be

incorporated into the clinical guideline development process. This type of testing could be conducted to investigate how the target staff group(s) interprets guidelines. Each policy or guideline standard could be tested by asking respondents to rephrase the standard in their own words. Also, ask respondents what process they would use to apply or implement the standards in their own care settings and also discuss how they would evidence compliance.

The benefit of this technique is that it supplies data on the end-users' comprehension and interpretation of guidelines and policies in the *'real-world'* setting.

Potentially, if staff groups interpret guidelines as intended by clinical guideline developers this may subsequently lead to better guideline compliance. Conversely, if clinical guideline developers had a greater understanding of the processes used by staff groups to interpret guidelines, they may (tailor) write or structure guidelines to promote uptake by healthcare professionals. Also, the uptake of clinical guidelines in hospitals is not routinely investigated by guideline producing bodies or organisations. The investigation into interpretation of guidelines could elucidate the reasons for lack of uptake in hospitals.

One of the key findings of this research project is that there was ambiguity of terminology used in the literature and this was reflected in the research interviews conducted in Study 1 and Study 2. Both groups of HCPs interviewed used different terms to refer to the same document or process. These findings indicate that there is a need for standardising terminology across care settings and staff groups such as international harmonisation of pharmacy-related terminology.

7.7. Implications for healthcare professionals

There is a need to identify and tailor interventions to local settings. However, there should be emphasis on the sustainability of interventions and ensuring that effective interventions are sustained for implementing ASPs. Limitations such as financial, specialist education level and allocation of resources can restrict the nature and type of interventions utilised in AMS. A multidisciplinary approach to AMS is therefore required to address these *'knowledge'* gaps. Longitudinal ASAT responses from individual trusts might offer a process indicator as a means for assessing trusts' level of AMS and enable benchmarking to be undertaken.

7.8. Future research

As previously discussed in *section 7.4*, the primary aim of this programme of work was to validate and improve the ASAT. However, the data collected from the qualitative studies provided pertinent insight into the current status of ASPs across Northwest SHA. These data highlighted that there are several areas which require further research in order to improve ASPs in NHS trusts.

In this research project, the ASAT was used to evaluate ASPs of participating NHS trusts. However, there were no comparative analyses conducted at a NHS trust-level and a SHA-level or regional level. Subsequently, an area of future research could involve utilising the ASAT to evaluate NHS trusts across England therefore facilitating comparative analyses between NHS trusts, and at a SHA-level or regional level and national level. These analyses could elucidate whether there are differences in the methods of implementation of ASPs across organisations such paediatric and specialist care trusts and also highlight gaps in service provision nationally. Subsequently, this could generate ideas for service improvement for ASPs.

The perspectives of the key personnel involved in the antimicrobial prescribing pathway could be investigated utilising a qualitative approach (semi-structured interviews). The healthcare professionals that could be targeted are those who prescribe, administer and staff that dispense antimicrobials in order to examine the roles of these healthcare professionals in ASPs. Other staff groups such as clinical microbiologists who may not be directly involved in prescribing but are involved in the prescribing decision could also be targeted. These data could provide insight on antimicrobial prescribing from the perspective of these staff groups and identify the strengths and weaknesses of local ASPs and also identify any missing or additional questions required for the ASAT such as the questions in *section 4.6.1.3*. This study could be conducted in conjunction with an investigation into patients' perspectives on antimicrobial chemotherapy.[352] This type of investigation could be used to enhance interventions for promoting medication adherence in patients on antimicrobials. Consequently, these data could be used as part of the education and training strategies for healthcare professionals involved in antimicrobial prescribing as stipulated by the SACAR Antimicrobial Framework. Therefore, ensuring improved continual education for staff involved in antimicrobial prescribing. These studies could be conducted in conjunction which antimicrobial prescribing audits for example

using the five indicators of antimicrobial prescribing as stipulated in START SMART and FOCUS.[24]

Additionally, there was a dearth of research studies identified from the literature review which investigated the sustainability of interventions for promoting hospital-based research. Also, there was limited discussion on the sustainability strategies that hospitals used to ensure that desired outcomes were maintained post-study. For example, linking organisational implementation evaluations (organisational-level data) with prescriber-level data in order to determine efficacy of hospital-based ASPs. The determination of the specific data requirements of relevant personnel to implement sustainable changes in improving prescribing should be investigated and also how the data are utilised by stakeholders. Therefore, further research is required to identify effective strategies for ensuring the sustainability of ASPs and also to identify which staff group(s) are most suitable to lead these interventions. It is anticipated that these studies would be conducted in conjunction with cost analyses of ASPs in order to determine the financial burden or cost implications on the hospital budgets.[353;354] Furthermore, health systems/services responsiveness research into the efficacy of implementing ASP performance indicators could be conducted.[326]

As discussed in Chapter 1, there is a lack of high quality studies investigating the efficacy of ASP-related interventions and their cost implications to the NHS. Therefore, high quality and robust research studies are required to investigate which interventions are most efficacious and sustainable. These findings of such studies could be used to determine the appropriate weightings and scores for each sub-section of the ASAT. Also, the data obtained for respondents indicated that the weightings of the ASAT sections should be investigated further in order to make an ASAT evaluation an informative and valid process *(see section 3.6.5.4)*.

As discussed in *section 7.5*, it can be seen that further research is required to investigate and identify sensitive structure, process and outcome indicators for AMS. National or regional representation of relevant healthcare professionals should be included in the development of prescribing measures in order to improve validity and credibility.[355] Therefore, in this programme of work, it was decided that the investigation of the validity of the ASAT would include relevant healthcare professionals such as antimicrobial pharmacists but also validity testing was

conducted at a regional and national level. However, as previously discussed, these studies were subject to sampling and response bias.

Therefore, there should be a national and international harmonisation for the development of these measures. For example, for reporting outcomes ASP-related interventions, there are standardised reporting guidelines for antimicrobial use such as the WHO Guidelines for ATC classification and DDD assignment.[208] However, there is no standardised definition of outcomes such as clinical success or clinical failure. Recommendations have been suggested for the standardised reporting of methodological information in research publications on hospital antimicrobial use *(see table 1.16)*. However, further work is required to determine the most appropriate measures for evaluating ASPs. Health outcomes data are useful for identifying barriers to implementing processes of care. However, rigorous, standardised methods of data collection and risk adjustment methods are required in order for accurate interpretation of outcomes data.[356]

Table 1.16: Recommendations for reporting methodological information in publications on hospital antimicrobial use[203]

Reporting methodological information in publications on hospital antimicrobial use	
1	Report hospital size, composition e.g. type of intensive care units, with or without bone marrow transplant or burn units etc. and also affiliation
2	Report mean length of stay, total number of bed days, number of patients admitted and numbers of admissions of individual patients to multiple hospital sites
3	Describe in detail the hospital wards that were included in the analysis, independently summarised all wards (including intensive care units), 'all intensive care units' and 'all wards' excluding intensive care units
4	Report DDD/100 bed days and DDD/100 admissions
5	Provide a clear definition of the term 'bed-day', count admission and discharge day together as 1 bed-day if possible
6	Report the version of the 'WHO guidelines for ATC classification and DDD assignment' that were used and use the most recent version at the time of publication
7	Select antimicrobials according to ATC classification. Include all drugs of ATC group 'J01' (antibiotics) and/or ATC group 'J' (antimicrobials)
8	For antibiotic use data in paediatrics, use days of therapy (DOTS) instead of DDDs, if possible

Nb. Antibiotics are all substances of ATC group 'J01' (antibiotics for systemic use). Antimicrobials are all substances of ATV group 'J' (anti-infectives for systemic use, including antibiotics for systemic use, antimycotics for systemic use, antimycobacterials, antivirals for systemic use, immune sera and immunoglobulins and vaccines). DDD (defined daily dose), ATC (anatomical therapeutic chemical classification index for antibiotics)

As previously mentioned, one of the main challenges of developing composite measures is the determination the appropriate weightings for component measures.[326] Component measures within the ASAT maybe weighted according to the priorities of relevant stakeholders involved in implementing hospital-based ASPs

such as antimicrobial pharmacists and clinical microbiologists. Further research is recommended into the investigation of the most appropriate weightings for the ASAT's component measures and domains which are required for an informative evaluation of ASPs. Therefore, based on the results of an ASAT evaluation, hospitals could prioritise their resources into developing effective ASPs. Additionally, further validity studies are required into the usage of a *'don't know'* or '*data unavailable'* options for respondents. It is anticipated that this option would be used when respondents are unaware and cannot recall the current practice(s) which questions are targeting.

Rasch models are probabilistic in nature, therefore, *'item difficulty'* or *'item hierarchy'* was only determined from the responses to ASAT v17 in Study 3. Therefore, this further supports the research recommendation for determining the weights of the questions within the ASAT by the strength of evidence underpinning each question and also consensus process such as the Delphi method.

7.9. Conclusion

The principles aims of this programme of work were to investigate the validity of the ASAT and consequently improve its validity from the findings. The results from Study 1 indicated that the ASAT required modifications in order to improve its content validity. The cognitive interviews conducted with AMPs highlighted a number of areas for improvement of the ASAT. Comprehension problems were reported within each domain of ASAT v15a which highlighted that there was a lack of standardised terminology used in reference to antimicrobial control documentation.

These findings were reflected in Study 2, where clinical microbiologists were interviewed using ASAT v16. These respondents highlighted the issue regarding the numerous terms used when describing antimicrobial control documents. Also, they indicated that the role of clinical microbiologist was pertinent to the success of implementation strategies for ASPs. This was as a result of the medical training they receive on patient care and also the specialist training on infection management.

The Rasch modelling identified that there was homogeneity within the responses to ASAT v17. This was to be expected because the questions in the ASAT are based on policies published by the DH some of which are mandatory. Therefore, it would be expected that NHS trusts would report compliance to these recommendations within the DH policies. The invariability of responses affected the simple OLS

regression modelling conducted on the Rasch estimates of NHS trust *'ability'* scores on these domains and also the CDI rates for participating NHS trusts. The resulting associations were very weak or non-existent. This limited the ability of the OLS regression modelling to investigate the predictive validity of ASAT v18. Also, CDI rates can be subjected to confounders so therefore it may have not been the best indicator of the quality of ASPs.

As a consequence, it is recommended that further validity testing is required and essential before a future iteration of the ASAT can be used as a set of quality standards or as a benchmarking tool. Furthermore, the ASAT should be modified to reflect new research findings which are applicable to ASP implementation.

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APPENDIX I: Timeline or key milestones of antimicrobial policy development (UK)

Year	Organisation	Policy/Guidelines/Reports
1994	British Society for Antimicrobial Chemotherapy (Working Party)	Hospital antibiotic control measures in the UK – Working Party Report. http://jac.oxfordjournals.org/cgi/reprint/34/1/21.pdf
March 1995	Department of Health (DH)	Hospital Infection Control guidance on the control of infections in hospitals. Published by the Hospital Infection Working Group of the Department of Health and Public Health Laboratory Service. http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4012329.pdf
1997	Department of Health (DH)	Chief Medical Officer asked the Standing Medical Advisory Committee (SMAC) to examine the issue of antimicrobial resistance in relation to medical prescribing.
March 1998	House of Lords	Select Committee on Science and Technology – Seventh Report Resistance to antibiotics and other antimicrobial agents. Published March 17th, 1998. http://www.parliament.the-stationery-office.co.uk/pa/ld199798/ldselect/ldsctech/081vii/st0701.htm
Sept 1998	Department of Health (DH)	SMAC (Standing Medical Advisory Committee) Sub-group on Antimicrobial Resistance published The Path of Least Resistance) http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4120729.pdf
March 1999	Department of Health (DH)	Resistance to antibiotics and other antimicrobial agents (HSC 1999/049) http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4012033.pdf
1999	British Society for Antimicrobial Chemotherapy (BSAC)/ Hospital Infection Society (HIS)	Working party on optimisation of antibiotic prescribing in hospitals created.
Feb 2000	National Audit Office (NAO)	The Management and Control of Hospital Acquired Infection in Acute Trusts in England http://www.nao.org.uk/publications/9900/hospital_acquired_infection.aspx
June 2000	Department of Health (DH)	UK Antimicrobial Resistance Strategy and Action Plan http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4007783

Year	Organisation	Policy/Guidelines/Reports
2000	Department of Health (DH)	The Management and Control of Hospital Infection: action of the NHS for the management and control of infections in hospitals in England. Health Service Circular: HSC (2000)002 http://www.dh.gov.uk/en/Publicationsandstatistics/Lettersandcirculars/Healthservicecirculars/DH_4004217?IdcService=GET_FILE&dID=3902&Rendition=Web
June 2001	Department of Health (DH) The Interdepartmental Steering Group on resistance to Antibiotics and other Antimicrobial Agents - Clinical Prescribing Subgroup	Optimising the clinical use of antimicrobials. Report and recommendations for further work. http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4084394
2001	Department of Health (DH)	SACAR (Specialist Advisory Committee on Antimicrobial Resistance). UK wide advisory committee to provide expert scientific advice on resistance issues arising from medical, veterinary and agricultural use of antimicrobials. (Cooke 2007) Nb. The Prescribing Sub-group advises SACAR on aspects of prudent antimicrobial prescribing.
Jan 2002	Department of Health (DH)	Getting Ahead of the Curve: A strategy for combating infectious diseases (including other aspects of health protection) http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4007697
2003	Department of Health (DH)	National Database for the use of antimicrobial agents in hospitals. This was a 3-year initiative which was overseen by the Prescribing Sub-group. The main aims of the database were to promote prudent antimicrobial prescribing through enhanced clinical pharmacy activity, also known as the Pharmacy Initiative.
June 2003	Department of Health (DH)	Hospital Pharmacy initiative for promoting prudent use of antibiotics in hospitals http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/documents/digitalasset/dh_4013409.pdf
Dec 2003	Department of Health (DH)	Winning Ways: Working together to reduce Healthcare Associated Infection in England. http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4064682

Year	Organisation	Policy/Guidelines/Reports
2004	Department of Health (DH)	Towards cleaner hospitals and lower rates of infection: A summary of action http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4085649
2004	National Audit Office	Improving patient care by reducing the risk of hospital acquired infection: a progress report http://www.nao.org.uk/publications/0304/improving_patient_care.aspx
Sep 2005	Scottish Medicines Consortium (SMC). The Scottish Executive Health Department Healthcare Associated Infection task Force	Antimicrobial prescribing policy and practice in Scotland: recommendations for good antimicrobial practice in acute hospitals http://www.scotland.gov.uk/Publications/2005/09/02132609/26099
2006	Department of Health (DH)	The Health Act 2006: Code of Practice for the Prevention and Control of Healthcare Associated Infections (revised 2008) http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyandGuidance/DH_4139336
2007	Healthcare Commission (now Care Quality Commission - CQC)	The Best Medicine: The Management of Medicines in Acute and Specialist Trusts http://archive.cqc.org.uk/_db/_documents/The_Best_Medicine_acute_trust_tagged.pdf
2007	Department of Health (DH)	Saving Lives: reducing infection, delivering clean and safe care http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_078134
2007	SACAR	Specialist Advisory Committee on Antimicrobial Resistance (SACAR) publishes and Antimicrobial Framework http://jac.oxfordjournals.org/content/60/suppl_1/i87.full
2007	Commission for Healthcare Audit and Inspection now Care Quality Commission (CQC)	Healthcare associated infection: What else can the NHS do? http://www.cqc.org.uk/_db/_documents/HCAI_Report_2_200801223430.pdf
2007	Department of Health (DH)	Essential Steps to Safe, Clean Care: Reducing Healthcare-Associated Infections http://webarchive.nationalarchives.gov.uk/+/www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4136212

Year	Organisation	Policy/Guidelines/Reports
2008	Department of Health (DH)	Clean, Safe Care: Reducing Infections and Saving Lives http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_081650
2008	Department of Health (DH)	High care for all NHS Next Review Stage Review Final Report http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_085825
2008	Department of Health (DH)	Board to ward: How to embed a culture of HCAI prevention in Acute trusts (2008) http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_112195.pdf
2009	Department of Health (DH)	The Health and Social Care Act 2008: Code of Practice for health and adult social care on the prevention and control of infections and related guidance http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_110288
2009	Department of Health (DH) and HPA	Clostridium difficile infection: how to deal with the problem http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_093218.pdf
2009	National Audit Office	Reducing healthcare associated infections in England http://www.nao.org.uk/publications/0809/reducing_healthcare_associated.aspx
2011	Department of Health (DH)	Antimicrobial stewardship: Start smart - then focus http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_131062
2011	Department of Health (DH) and HPA	Prevention and control of healthcare-associated infections quality improvement guide (2011) http://www.nice.org.uk/aboutnice/whatwedo/aboutpublichealthguidance/healthcare-associated-infections/qualityimprovementguide.jsp?domedia=1&mid=8333C688-19B9-E0B5-D45AD3EADFA65CC0
2012	Health Protection Agency	English National Point Prevalence Survey on Healthcare-associated Infections and Antimicrobial Use, 2011: preliminary data http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317134304594

Appendix II: Summary of results of included studies that investigated interventions to improve antimicrobial prescribing in hospitals

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Adachi (1997)[165] **GRADE LOE** : $2^+/2^-$ (Medium risk of bias)	**ITS** **Participants:** all hospitalised patients (unclear demographics) **Setting:** single hospital (US)	ID specialist (primary) Pharmacist (supplementary)	**Main:** Local guideline for vancomycin by ID specialist **Supplementary:** Vancomycin orders by order sheet were reviewed by pharmacists	Restriction associated with a sudden reduction in level by $136 *(p=0.037)* and sustained reduction in slope by $15 per quarter *(p=0.028)*
Ansari (2003)[175] **GRADE LOE :** 2^+ (Low risk of bias)	**ITS** **Participants:** all hospitalised patients **Duration:** Pre-intervention: 2 years Post-intervention: 2 years **Setting: single hospital** (UK)	Multidisciplinary Antimicrobial team	**Main:** Local policy for alert antimicrobials **Supplementary:** Dissemination to prescribers via web and also printed copies. Clinical pharmacists provided audit with feedback to prescribers.	Costs of Alert Antimicrobials decreased by an average of £28,852 per month (95% CI £18,154 to £29,549, *p< 0.0001*) after intervention.
Arnold (2006)[145] **GRADE LOE** : $2^+/2^-$ (Medium risk of bias)	**ITS** **Sample:** 2807 antimicrobial courses **Duration:** Pre-intervention: 9 months Post-intervention: 9 months **Setting:** 110-bed hospital (affiliation undeclared) (US)	Antimicrobial management team (composition undeclared)	**Main:** Audit and feedback Feedback comprised of weekly aggregated reports on compliance, quarterly department-specific reports on compliance and a monthly newsletter on pertinent aspects of feedback reports and infectious diseases-related topics (educational)	Post-intervention 93% of antimicrobial courses were compliant. However, the expenditure on antimicrobials and the percentage of patients with new colonisation or infection of MRSA was almost equivalent between the two periods.
Avorn (1988)[149] **GRADE LOE** : $2^+/2^-$ (Medium risk of bias)	**ITS** **Participants**: unclear demographics **Setting**: 460-bed single hospital (US)	Multidisciplinary team (MDT)	**Main:** Parenteral antimicrobial order form by MDT (unrestrictive) **Supplementary:** educational sessions with house officers, nurses and others, reminders and ward posters	Incorrect dosing of cefazolin, clindamycin and metronidazole fell by 60%, 90% and 75% respectively and annual drug costs for targeted AMs were estimated to be $44,500, $9400 and $5400 respectively.

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Bailey (1997)[132] **GRADE LOE** : $1^{+}/1^{-}$ (Medium risk of bias)	**RCT** **Participants:** 102 inpatients **Duration**: Hospital A: 6 months Hospital B: 3 months **Setting:** 2 tertiary care teaching hospitals Hospital A: 1000 beds Hospital B: 400 beds (US)	Pharmacist	**Main:** Review and change prescriptions as appropriate such as discontinuation of IV therapy by IV to oral switch	Reduction in mean IV antimicrobial days in both hospitals where Hospital A (1.0 days) and hospital B (1.5 days). The need to restart IV antimicrobials and also in-hospital mortality were not statistically significant between study groups.
Belliveau (1996)[126] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** 386 courses of vancomycin **Setting:** 388-bed teaching hospital (US)	Pharmacist	**Main:** Restrictive order form (vancomycin) **Supplementary:** audit and feedback by ID pharmacist and/or ID physician **Desired change:** reduction in inappropriate vancomycin use	Significant reduction in vancomycin use based on a t-test (8 weeks pre vs. 8 weeks post and 12 months pre vs. 14 months post).
Berild (2002)[166] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS:** **Participants:** (304 children surveyed) **Setting:** 46 bed paediatric unit in an University hospital (Norway)	Local expert (undeclared) (primary) ID Physician Microbiologists (supplementary)	**Main:** Local antimicrobial guidelines **Supplementary**: lectures on antimicrobial prescribing for newly employed doctors (education) and meetings with ID Physicians and microbiologists	Intervention was associated with sudden reduction in level by 6.9 DDD/100bed days *(p=0.011)* and by £181/100 bed days *(p=0.006)*

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Bevilacqua (2011)[127] **GRADE LOE** : $1^{+}/1^{-}$ (Medium risk of bias)	**Clustered clinical trial** **Sample**: patients admitted on study wards Phase 1: 194730 bed days Phase 2: 176613 bed days **Duration:** 24 months **Setting:** 1800-bed split site hospital *Nb. The infectious and tropical diseases wards were excluded* (France)	Operational multidisciplinary antimicrobial team (OMAT)	**Main**: Ward rounds triggered by inappropriate antimicrobial use (pharmacists) **Supplementary:** compulsory order form and review and feedback to prescribers by an ID physician, one clinical pharmacists and one microbiologist.	Post-implementation antimicrobial consumption decreased (33.6% vs. 3.3%; *p=0.003)*. Annual savings for antimicrobials was approximately €603 900 in intervention group.
Borer (2004)[142] **GRADE LOE:** 1^{-} (High risk of bias)	**RCT** **Participants:** all hospitals patients *i.e.* 402 patients community acquired febrile syndromes **Duration:** 4 months **Setting:** 1000-bed tertiary care teaching facility (Israel)	ID physicians	**Main:** Guidelines (review and change) **Supplementary:** (unclear)	Antimicrobial therapy was more appropriate in the intervention group than control group (55.5% vs. 43%; *p=0.012*).
Bouza (2004)[143] **GRADE LOE:** 1^{-} (High risk of bias)	**RCT** **Participants:** 297 patients with blood stream infections. **Duration:** 6 months (February 2000 to July 2000) **Setting:** a single 1750-bed teaching hospital (Spain)	ID physicians	**Main:** Audit with feedback (review and change) Group A: conventional information Group B: written report on the clinical chart Group C: oral alert report **Supplementary:** not declared	Intervention groups reported improved antimicrobial decision making for example route of administration (98.4 ± 9.8 vs. 88.0 ± 27.8; *p<0.001*). Mean costs of inappropriate antimicrobial therapy lower for Group B (US$ 48.53) and Group C (US$ 43.86)

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Bradley (1999)[116] **GRADE LOE** : $2^+/2^-$ (Medium risk of bias)	**ITS** **Participants:** 261 patients **Setting:** 35-bed adult haematology unit (UK)	Undeclared lead	**Main:** Antimicrobial policy replacing ceftazidime with piperacillin/tazobactam for initial treatment febrile neutropenia	Acquisition of GRE fell from 57% in phase 1(ceftazidime) to 19% in Phase 2 (piperacillin/tazobactam) and 36% (ceftazidime)
Bruins (2005)[179] **GRADE LOE:** 1^- (High risk of bias)	**RCT** **Participants:** 1883 patients (1^{st} sample containing clinically relevant isolates e.g. *Pseudomonas aeroginosa* **Duration:** 9 months **Setting:** 1100-bed university hospital (Netherlands)	Physicians (unclear designation)	**Main**: Rapid susceptibility testing (Vitek 2 system) **Supplementary:** Oral and written reports of results	Microbiological data were available more rapidly in intervention groups [49 (30.0-75.0) vs. 53.3 (50.0 -76.39)] No significant differences in clinical outcomes across study groups were reported
Buising (2008)[150] **GRADE LOE** : $2^+/2^-$ (Medium risk of bias)	**ITS** **Participants:** CAP patients admitted via Emergency department (ED) **Duration:** Baseline: 12 months Phase 2: 6 months Phase 3: 6 months **Setting:** 350-bed single adult tertiary teaching hospital (Australia)	Undeclared	**Main:** Baseline: electronic and paper copies of national antimicrobial guidelines available (no additional encouragement to uptake) (Baseline) Academic detailing (AD) by two ED physicians, a pharmacist, and a nurse provided 1:1 AD to their colleagues (Phase 1) Computerised decision support system (CDSS) (Phase 2) *Nb. A computerised antimicrobial approval system restricting access to ceftriaxone was in operation during the study*	Odds ratio for concordant therapy in AD period after adjustment for age, illness severity and suspicion of aspiration, compared with baseline was OR =2.79 [1.88,4.14], *p<0.01* and for the CDSS period compared to AD period was OR =1.99[1.07,3.69], *p=0.02.* An improvement in antimicrobial prescribing was demonstrated in the first months of CDSS period which was greater than in the AD period.

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Burton (1991)[181] **GRADE LOE** : $1^{+}/1^{-}$ (Medium risk of bias)	**RCT** **Participants:** 147 patients **Setting:** single 680-bed tertiary care hospital (US)	Undeclared	**Main:** Bayesian dosing program **Supplementary:** undeclared	Higher peak aminoglycoside level in study group (5.3 vs.4.3mg/l, p=0.001). Mean LOS 4.3 days shorter in study group. Trend towards better response to therapy (86% vs. 73%) and lower nephrotoxicty (5.6% vs. 9.3%)
Calil (2001)[117] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** 342 patients **Setting:** a 30-bed neonatal unit (Brazil)	Undeclared lead	**Main:** new antimicrobial policy eliminating the use of 3rd generation cephalosporins **Supplementary:** not declared	Sudden decrease in level by 15.51 cases per month *(p=0.054)* and sustained decrease in slope by 2.73 cases per month *(p=0.138)*
Camins (2009)[139] **GRADE LOE** : $1^{+}/1^{-}$ (Medium risk of bias)	**RCT** **Participants:** 784 new prescriptions of piperacillin-tazobactam, levofloxacin, or vancomycin from 380 patients **Duration:** 10 months **Setting:** single 953-bed university teaching hospital (US)	Antimicrobial utilisation team (AUT)	**Main:** audit and feedback by AUT which was composed of an ID physician and an ID clinical pharmacist with close links to microbiology. Structured feedback included verbal feedback by phone or face to face meetings **Supplementary:** indication-based antimicrobial prescribing guidelines	Physicians in the intervention group were more likely to use antimicrobials appropriately. Feedback from the AUT resulted in a significantly higher proportion of appropriate initial antimicrobial therapy in the intervention group (78% vs. 58%; RR, 1.35). A higher proportion of end antimicrobial use was observed in the intervention group (94% vs.70%; RR, 1.34).

STUDY/LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Carling (2003)[136] **GRADE LOE** : 2^+ (Low risk of bias)	**ITS** **Participants:** unclear **Setting:** single medium sized hospital (US)	MDT led ID physician and ID Pharmacist	**Main:** local consensus policy (multifaceted) and review with feedback on all patients on aztreonam and third generation cephalosporins, parenteral fluoroquinolones, or imipenem **Supplementary:** Academic detailing between pharmacists and prescribers	6.2 DDD/1000 bed days achieved after intervention. Post-intervention: Reduction in level and slope for infections caused by *C.difficile (p=0.002)* and *Enterobacteriaceae (p=0.02)* but not for MRSA and VRE
de Champs (1994)[118] **GRADE LOE** : 2^- (High risk of bias)	**ITS** **Participants:** 636 neonates **Setting:** paediatric ICU (France)	Undeclared lead	**Main:** change in antimicrobial policy from gentamicin to amikacin **Supplementary:** not declared	Significant reduction in the number of infections with multi-resistant *E.cloacae*, sudden reduction in level by 7.5 cases *(p<0.0001)* and sustained change in slope by 1 case per month *(p=0.002)*
Charbonneau (2006)[115] **GRADE LOE:** $2^+/2^-$ (Medium risk of bias)	**ITS** **Participants:** all admitted patients requiring oral or parenteral fluoroquinolones **Duration:** 12 months **Setting:** 4 large teaching hospitals (France)	ID consultants	**Main:** Pre-approval **Supplementary:** Guidelines (therapeutic substitution) written by ID consultant and also guideline dissemination to all prescribers	Reduction in the use of fluoroquinolones in intervention hospital (5.2 vs. 53.6 DDDs per 1000 bed days.
Christ-Crain (2004)[184] **GRADE LOE:** $1^+/1^-$ (Medium risk of bias)	**RCT** **Participants:** 597 LRTI patients (randomised); 243 patients met inclusion criteria **Duration:** 4 months **Setting:** a single university hospital (Switzerland)	Unclear	**Main:** Novel biomarker testing - Procalcitonin **Supplementary:** antimicrobial policy/ diagnostic pathway written by MDT	Relative risk of antimicrobial exposure in LRTI patients was 0.39 (95% CI: 0.36-0.42; *p<0.0001*) in procalcitonin group. Also, relative risk reduction was 50% (95% CI: 47-53; *p<0.001*)

STUDY/LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Christ-Crain (2006)[185] **GRADE LOE:** $1^{+}/1^{-}$ (medium risk of bias)	**RCT** **Participants:** 302 patients with suspected CAP **Duration:** 16 months **Setting:** a single university hospital (Switzerland)	Unclear	**Main:** Novel biomarker testing - Procalcitonin **Supplementary:** written procalcitonin guidelines with reminders	Use of procalcitonin-guided therapy was effective at reducing outcomes such as total antimicrobial exposure (RR:0.52; 95% CI:0.48-0.55; *p<0.001)*
Climo (1998)[105] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** all hospitalised patients **Setting: 703**-bed tertiary care centre (US)	ID consultant	**Main:** clindamycin use required approval from ID consultant (pre-approval) **Supplementary:** not declared	Sudden decrease in level by 26.3 cases of CDAD per quarter *(p<0.001)*, sustained decrease in slope by 3.8 cases per quarter thereafter.
Dempsey (1995)[167] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** 225 patients **Setting:** 814-bed teaching and referral centre (US)	MDT (primary)	**Main:** Clinical guideline developed by MDT **Supplementary:** audit meetings, monthly feedback to all medical staff, ancillary departments and committees	Decrease in LOS and hospital charges *Nb. Both of these outcomes were decreasing before the start of the study.* No significant change in level or slope.
Destache (1990)[182] **GRADE LOE** : 1^{-} (Very high risk of bias)	**RCT** **Participants:** 200 patients **Setting:** single tertiary hospital (US)	Undeclared lead	**Main:** Educational (clinical pharmacokinetic service with advice about dosing) **Supplementary:** (none declared)	32% of study group were excluded because their physicians did not follow advice. Study evidence too flawed to be interpretable.
Doern (1994)[177] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**CCT** **Participants:** 573 patients **Setting:** single University hospital (US)	Undeclared	**Main:** Rapid antimicrobial susceptibility testing **Supplementary:** undeclared	Time to availability of susceptibility results was 9.6h (study group) and 25.9h (control).

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Dranitaris (2001)[133] **GRADE LOE**: $1^{+}/1^{-}$ (Medium risk of bias)	**RCT** **Participants:** Adult patients requiring IV therapy. 323 episodes were randomised **Duration:** 6 months **Setting:** 2 hospitals (Canada)	Pharmacists	**Main:** Review with feedback against local guidelines on cefotaxime use **Supplementary:** Educational outreach visit	75% of study group prescriptions were compliant with guidelines. Indication (81% vs. 80%), dosage (94% vs. 86%; *p=0.018*), mean duration of therapy (4.3 days vs. 4.1 days; *p=0.28* and mean cost of therapy $198 vs. $245; *p=0.32*).
Elligsen (2012)[146] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** patients on the 3rd or 10th day of broad spectrum antimicrobials **Duration:** unclear **Setting:** single tertiary care centre (Canada)	Undeclared	**Main:** Audit and feedback with recommendations to prescribers **Supplementary:** none declared	Monthly use of broad spectrum antimicrobials decreased from 644 to 503 days per 1000 patient bed days. Incidence of nosocomial *C.difficile* infection decreased from 11 cases to 6 cases (intervention group). LOS and mortality did not change over between the two groups.
Everitt (1990)[151] **GRADE LOE** : 2^{+} (Low risk of bias)	**ITS** **Participants:** 2783 caesarean sections **Setting:** single teaching hospital **Duration:** 34 months. (US)	Undeclared lead	**Main:** Educational (local guideline disseminated to key department leaders and discussed at grand rounds **Supplementary:** Removal of cefoxitin from labour and delivery area (restrictive). Cefazolin recommended for surgical prophylaxis on educational antimicrobial form.	Almost complete substitution of cefazolin for cefoxitin for caesarean sections receiving <5g of either drug. Estimated annual savings of $26711.

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Fine (2003)[144] **GRADE LOE:** 1^- (High risk of bias)	**RCT (Cluster)** **Sample:** CAP patients (≥ 18 years of age) **Intervention:** 283 patients **Control:** 325 patients **Duration:** 12 months **Setting:** 7 hospitals (US)	Undeclared	**Main:** CAP guidelines, an educational mailing to physicians and also a daily assessment of patient's stability **Supplementary:** reminders (IV to oral switch in 3 sites), audit and feedback to attending physicians	In the intervention group the median duration of therapy was 3 days vs. 4 days in the control group, IV therapy was discontinued more rapidly (HR=1.23;95%CI:1.00 to 1.52, *p=0.06*). Shorter LOS in intervention group however this was not statistically significant. There were no significant differences in the other outcomes such mortality between the two groups.
Fowler (2007)[147] **GRADE LOE** : $2^+/2^-$ (Medium risk of bias)	**ITS** **Participants:** 6149 consecutive admissions aged ≥80 years **Duration:** 42 months **Setting:** 3 medical wards in a teaching hospital (UK)	Undeclared	**Main:** antimicrobial policy restricting cephalosporins (decrease use) and recommending less use of benzyl penicillin, trimethoprim and amoxicillin **Supplementary:** audit and feedback on individual antimicrobial usage and also CDI and MRSA rates. Doctors were also given pocket laminated versions of antimicrobial guidelines	Antimicrobial policy was associated with significant changes in targeted antimicrobial use. An increased use in all targeted narrow spectrum antimicrobials was observed and a reduction in targeted broad spectrum antimicrobials was also observed. CDI rates decreased with incidence ratios of 0.35 (95%CI,0.1-0.73; *p=0.09*) and MRSA incidence was unchanged.
Foy (2003)[169] **GRADE LOE: 1$^-$** (High risk of bias)	**Cluster RCT** **Participants:** 1474 patients (induced abortion care) **Duration:** **Setting:** 26 gynaecology wards (Scotland)	Clinicians	**Main:** Guidelines disseminated to fellows and members of the Royal College of Gynaecologists **Supplementary:** Audit with feedback to the intervention group	Multifaceted strategy was reported as ineffective for both primary and secondary outcomes.

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Franz (2004)[186] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**RCT** **Participants:** 1291 neonates (<72 hours of age) with suspected bacterial infection **Duration**:6 months **Setting:** 8 centres in five countries	Physicians (neonatal)	**Main:** Novel biomarker testing (IL-8 or CRP) **Supplementary:** Written information and flow diagram of decision making (diagnostic) pathway	Reduction of unnecessary antimicrobial therapy. However, proportion of initially missed infections was similar in study groups (14.5% (IL-8) vs. 17.3%; *p=0.076*)
Fraser (1997)[134] **GRADE LOE** : 1^{-} (High risk of bias)	**RCT** **Participants:** 225 patients **Duration:** 3 months **Intervention group:** 141 pts **Control group:** 111 pts **Setting:** single teaching hospital (US)	ID Fellow Clinical pharmacist	**Main:** Review and change (recommendations placed in medical notes) **Supplementary:** (none declared)	Antimicrobial charges were nearly $400 less per patient in study group *(p=0.05).* Trend towards less frequent antimicrobial re-treatment (4.7% vs.13.3%; *p=0.02)* and also shorter LOS (20 vs. 24.7 days; *p=0.11*)
Gums (1999)[135] **GRADE LOE:** 1^{+} (Low risk of bias)	**RCT** **Participants:** 272 patients **Duration:** 18 months **Setting:** single 275-bed community hospital (US)	Multidisciplinary ID service	**Main:** Review and recommend change within 2 hours of randomisation **Supplementary:** (none declared)	Post-intervention: LOS (5.7 days vs. 9.0 days) and mortality (6.3% vs. 12%; *p=0.175*)
Halm (2004)[170] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** all consecutive patients with pneumonia **Pre-intervention:** 1013 pts **Post-intervention:** 1081 pts **Duration:** 5 months (US)	MDT	**Main:** MDT developed treatment guidelines and critical pathways **Supplementary:** educational sessions with physicians, pocket reminders, developed bilingual patient education	Guideline compliance increased from 78.1% to 83.4% (p=0.003). No change observed in other indicators such as time to 1^{st} dose, timely IV to oral switch, LOS and pt education outcomes

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Hess (1990)[152] **GRADE LOE** : $2^+/2^-$ (Medium risk of bias)	**ITS** Participants: all hospitalised patients **Setting:** 719-bed tertiary centre (US)	Undeclared lead	**Main:** Educational (several interventions), only standardised dosing with sufficient ITS data and clear intervention point) **Supplementary:** (none declared)	Sudden reduction in the level of cefazolin expenditure by $0.38 per day *(p=0.009)*. There was no change in slope over time after initial effect.
Himmelberg (1991)[120] **GRADE LOE** : $2^+/2^-$ (Medium risk of bias)	**ITS** **Participants:** unclear number of courses **Setting:** 660-bed teaching hospital (US)	On-call Fellow or Staff physician in adult or paediatric ID	**Main:** removal of restrictive use of 9 antimicrobials **Supplementary:** not declared	Removal of restriction was associated with a 158% in use (from 413 to 1064 courses) and a 103% increase in expenditure (from $154542 to $313905)
Hulgan (2004)[164] **GRADE LOE: 2^+** (Low risk of bias)	**ITS** **Sample:** 15194 IV and oral quinolone orders **Duration:** 5 months (105 weeks) **Setting:** a single university hospital (US)	Physicians	**Main:** computerised decision support system (CDSS) **Supplementary:** reminders as part of an order entry system	No significant effect detected post-intervention for oral quinolone orders.
Khan (2003)[121] **GRADE LOE** : $2^+/2^-$ (Medium risk of bias)	**ITS** **Participants:** hospital in-patients with *C. difficile* toxin detected in faeces **Duration:** 1995 to 2000 (5 years) **Setting:** a single 800-bed non-teaching district general hospital (UK)	Undeclared	**Main:** Restrictive change in antimicrobial policy from cefotaxime to ceftriaxone Method of restriction unclear. **Supplementary:** none declared	After changing to ceftriaxone there was a sudden increase in level by +19.7 cases per quarter *(p=0.074)* and a sustained level in slope by +4.7 cases per quarter *(p=0.073).* *Nb. Prior to the changes in antimicrobial policy CDAD rates were at -3.8 cases per quarter (p=0.115).*

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Kritchevsky (2008)[140] **GRADE LOE:** 1^+ (Low risk of bias)	**RCT** **Participants:** Surgical cases for cardiac, hip or knee replacement and hysterectomy **Duration:** 4 years **Setting:** 44 Acute care hospitals (US)	Undeclared	**Main:** Audit and feedback (comparative) in conjunction with enrolment in a quality improvement collaborative (TRAPE) **Supplementary:** none declared	The degree on improvement differed very little between the two groups e.g. the proportion of patients receiving prophylaxis for no more than 24 hours were no different between the two groups. The trial did not demonstrate any benefit from involvement in the quality improvement collaborative
Kumana (2001)[176] **GRADE LOE:** 2^+ (low risk of bias)	**ITS** **Participants:** Patients receiving glycopeptides (teicoplanin and vancomycin) **Duration:** 4 years **Setting:** a single hospital (Hong Kong)	Clinical pharmacist	**Main:** Antimicrobial guidelines **Supplementary:** reminders, audit with feedback (glycopeptides prescribing)	Guideline adherence increased by 54% *(p<0.0001)* post-intervention. Study reported a decrease in average monthly usage.
Landman (1999)[106] **GRADE LOE** : $2^+/2^-$ (Medium risk of bias)	**ITS** **Participants:** all hospitalised patients **Setting:** single University hospital (US)	ID physician	**Main:** use of 3rd generation cephalosporins, clindamycin and vancomycin (pre-approval by ID physician) **Supplementary:** not declared	Intervention was not associated with a significant reduction in incidence of ceftazidime-resistant *Klebsiella puemoniae* or MRSA.
Lautenbach (2003)[107] **GRADE LOE** : $2^+/2^-$ (Medium risk of bias)	**ITS** **Participants:** unclear **Setting:** single 725-bed University hospital (US)	Antimicrobial management programme	**Main:** vancomycin use required approval from Antimicrobial management programme (pre-approval)	No significant change in level or slope after intervention
Lee (1995)[153] **GRADE LOE** : 2^- (High risk of bias)	**ITS** **Participants:** 480 pts **Setting:** single teaching hospital (US)	Multidisciplinary antibiotic review team (MART) consisting of ID physicians and a pharmacist	**Main:** Educational meetings plus concurrent review by MDT **Supplementary:** not declared	Post-intervention: Sudden reduction in level of use of ceftriaxone by 589g per month

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
de Man (2000)[119] **GRADE LOE:** 1^{+} (Low risk of bias)	**CCT** **Participants:** 436 patients **Setting:** 2 NICUs in a single University hospital (Netherlands)	Undeclared lead	**Main:** change in antimicrobial policy from penicillin and tobramycin to amoxicillin and cefotaxime Supplementary: not declared **Desired change:** modification of established management	Amoxicillin and cefotaxime regimen associated with a RR of colonisation by Gram -ve bacteria resistant to empiric therapy of 17.98 (CI 5.78 to 58.01) and RR of colonisation by cefotaxime or tobramycin resistant bacteria of 2.98 (CI 1.64 to 5.38)
Masia (2008)[141] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**RCT** **Participants:** 253 adult pts (≥ 14 years) with 278 prescription of targeted antimicrobials **Intervention:** 146 prescriptions **Control:**132 prescriptions **Duration:** 6 months **Setting:** 470-bed university affiliated teaching hospital (Spain)	ID Physician and pharmacist	**Main:** Expert advice from ID physician with greater than 10 years experience based on antimicrobial guidelines Targeted antimicrobials: levofloxacin (IV or oral), vancomycin, and carbapenems **Supplementary:** none declared	Antimicrobial consumption was lower in intervention group (8 [4-12] DDDs/pt). Shorter duration of antimicrobial therapy in intervention group (4 [3-7] days per pt). No significant differences were observed between groups in number of deaths, hospital readmissions, LOS and antimicrobial costs. Interventions had limited efficacy and did not save costs.

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
McElnay (1995)[108] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** unclear **Setting:** single non-teaching hospital (UK)	ID physician (Consultant)	**Main:** restricted antimicrobials required countersignature by consultant Supplementary: not declared	Antimicrobial policy was associated with sudden reduction in level of antimicrobial cost by £859 per month *(p=0.141)*. Slope of antimicrobial cost increased significantly by £192 per month (p=0.004). Difference in slopes was an increase in antimicrobial cost by £103 per month after policy implemented
McNulty (1997)[122] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** 486 episodes with suspected infection in care of the elderly unit in DGH (UK)	Pharmacist	**Main:** Antimicrobial policy change for suspected infection to benzylpenicillin, gentamicin and trimethoprim. Restriction of IV cefuroxime and removal of oral cefuroxime from pharmacy stock **Supplementary:** Antimicrobial prescribing monitored by pharmacist	Intervention associated with a sudden reduction of CDAD by 3.22 cases per month *(p=0.120)* and a trend towards reduced slope (difference in slope -0.50 cases per month; *p=0.230*)
Mercer (1999)[109] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS with cost comparative analyses pre- and post intervention** **Participants:** unclear **Duration:** 24 months Pre-intervention: March 1995 to February 1996 Post-intervention: March 1996 to February 1997 **Setting:** 360-bed community hospital (US)	ID physician (Consultant)	**Main:** Pre-approval for 16 antimicrobials by ID physician and these were removed from Emergency department and operating room **Education:** Implementation on pneumonia clinical pathway by placing reminders in appropriate patient charts	Sudden decrease of $13687 of antimicrobial monthly costs *(p=0.07)* but no change in slope *(p=0.9).* IV antimicrobial usage decreased by greater than 22%

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Meyer (1993)[110] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** unclear **Setting:** single 487-bed University hospital (US)	ID physician (Consultant)	**Main:** ceftazidime use required countersignature by ID physician (pre-approval) Supplementary: barrier precautions for colonised and infected pts	Ceftazidime restriction was associated with a sudden reduction in level of infection caused by *Klebsiella puemoniae* by 38.6 cases *(p<0.0001)* and a sustained reduction by 6.2 cases *(p<0.0001)*
Meyer (2007)[171] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants**: bacteraemia patients (number of patients undeclared) **Duration:** undeclared **Setting:** a single neurological ICU (US)	Intensive care physician	**Main:** Guidelines (revised) by MDT (Intensive care specialists, IC physician, microbiologists and pharmacists) to reduce duration of antimicrobial therapy. Carbapenems were removed for late-onset nosocomial pneumonia. **Supplementary:** IC physician education of rotating neurosurgeons	Significant decrease in total antimicrobial usage density from 949.8 to 626.7 DDD/1000pd primarily due to the consumption of certain antimicrobials. Total antimicrobial costs/pd significantly decreased from 13.16 €/pd to 7.31€/pd post intervention. This resulted in a saving of 5.85 €/pd.
Micek (2004)[129] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**RCT** **Participants:** 290 pts (≥18 yrs and received treatment for ventilator-associated pneumonia (VAP) **Duration:** 18 months **Setting:** 1400-bed university affiliated teaching hospital (US)	Undeclared	**Main:** antimicrobial discontinuation policy clinically suspected VAP **Supplementary:** none declared	Duration of treatment for VAP was statistically shorter in the intervention group (6.0 ± 4.9 days vs. 8.0 vs. 5.6 days, *p=0.001*). However, there was no significant difference in the occurrence of a secondary episode of VAP, hospital mortality and ICU LOS. There was attrition bias due to loss of 12 patients from the study.

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Mol (2005) **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** 7471 antimicrobial prescriptions from 2869 pts **Duration:** 2 years **Setting:** 190-bed Department of Internal Medicine (The Netherlands)	Undeclared	**Main:** Antimicrobial treatment guidelines which were disseminated to physicians (intervention 1) and academic detailing in both individual and group sessions (intervention 2) **Supplementary:** none declared	Guidelines were associated with an immediate increase in compliance of 15% (95% CI: 8%; 23%; *p<0.001*) but this was not sustained. Educational sessions did not lead to further compliance. There was an non-significant decrease in antimicrobial costs of €151 (95%Cl: -€960;€658) after guidelines were disseminated
Naughton (2001)[154] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**RCT** **Participants:** 350 episodes **Setting:** 10 Skilled Nursing Facilities (SNFs), non-teaching (US)	Physician (specialty not declared)	**Main:** Educational. Physician-led groups with laminated cards **Supplementary:** Nurse-led training to small groups of nurses with opportunities to reflect on implementation barriers	Use of parenteral antimicrobials increased from 50% to 82% in study group and 65% to 69% in control group. Multivariate analysis adjusted for variations in occurrence and severity of pneumonia and found no significant difference in PA use *(p=0.13)* or mortality *(p=0.16)*
Oosterheert (2005)[180] **GRADE LOE:** 1^{-} (High risk of bias)	**RCT** **Participants:** 107 patients with LRTIs **Duration:** 18 months **Setting:** two hospitals (The Netherlands)	Physicians	**Main:** Rapid susceptibility testing by real-time PCR **Supplementary:** Written policy disseminated to prescribers	Limited or null effect reported on antimicrobial costs or usage.
Pastel (1992)[137] **GRADE LOE** : 1^{-} (High risk of bias)	**CCT** **Participants:** 241 patients (253 episodes) **Setting:** 1150-bed teaching hospital (US)	Pharmacist	**Main:** Review and feedback to physicians by pharmacists before microbiology results (empirically) and after microbiology results	Modifications to empirical prescribing were 11%. Results were similar for both groups after microbiology data was available.

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Paul (2006)[183] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**RCT (cluster)** **Participants:** **Duration:** 6 months **Settings:** 3 hospitals in Israel, Germany and Italy	Physicians	**Main:** Computerised decision support system (CDSS) - TREAT **Supplementary:** additional advice provided on using CDSS	TREAT improved empirical prescribing (73% vs. 64%) OR:1.48 (95% CL:1.03-2.11)
Patel (1989)[160] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** all hospitalised patients **Setting:** single hospital (UK)	Pharmacist (ward)	**Main:** Formulary information sheet distributed to all doctors recommending co-amoxiclav be restricted for amoxicillin resistant bacteria	Sudden reduction in level by £611.36 per month *(p=0.002)*. Reduction sustained for 5 months. Difference in pre- and post intervention slopes was -£48.69 *(p=0.248).*
Pear (1994)[111] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** unclear **Setting:** single University hospital (US)	ID physician (Consultant)	**Main:** change of clindamycin from formulary to non-formulary (restricted) and non-formulary prescriptions required pre-approval from ID physician	Clindamycin was associated with sudden reduction in level by 3.68 cases per month *(p=0.041)* and sustained reduction in slope by 0.32 cases per month *(p=0.134).*
Perez (2003)[128] **GRADE LOE** : 2^{+} (Low risk of bias)	**ITS** **Participants:** unclear **Setting:** single University hospital (Columbia)	Pharmacist	**Main:** compulsory antimicrobial order form for aminoglycosides, cephradine/cephalothin and ceftazidime/cefotaxime **Supplementary:** educational reinforcement for administration of surgical prophylaxis within 1 hr via reminders	Statistically significant effect for interventions, reduction in incorrect prescriptions for aminoglycosides, ceftazidime/cefotaxime at 47% and 7.3% respectively and 20% for surgical prophylaxis.

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Richards (2003)[112] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** unclear **Setting:** single university hospital (Australia)	Undeclared	**Main:** cefotaxime added to restricted list. Pre-approval and codes (antimicrobial approval number) **Supplementary:** cefotaxime removed from ward stocks and operating theatres	Sudden decrease in level of use of cefotaxime or ceftriaxone by 32.54 DDD per 1000 bed days *(p<0.001)*. Increase in gentamicin use by 13.91 DDD per 1000 bed days *(p=0.03)*.
Richardson (2000)[138] **GRADE LOE** : 2^{-} (High risk of bias)	**ITS** **Participants:** 618 episodes of vancomycin use (200 pre- and 398 post-intervention) **Setting:** single tertiary care centre (US)	Pharmacist (ID)	**Main:** review and feedback to recommend changes to non-compliant prescribing on vancomycin **Supplementary:** undeclared	Sudden reduction in inappropriate vancomycin prescribing by 20.6% *(p=0.131).*
Saizy-Calleart (2003)[113] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** unclear **Setting:** single 600-bed University hospital (France)	Physician (senior) Specialty (undeclared)	**Main:** most expensive antimicrobials required completion of named-patient prescription forms by senior hospital physician) **Supplementary:** Audit and feedback by pharmacists to prescribers (persuasive)	Programme not associated with any significant change in level of anti-infective expenditure *(p=0.981).*
Salama (1996)[130] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** unclear **Setting:** single 465-bed tertiary care hospital (Canada)	Undeclared	**Main:** Automatic 3-day stop order for all antimicrobials, therapeutic substitution of selected drugs, restriction of 8 antimicrobials by restricted antimicrobial order form **Supplementary:** Clinical guideline dissemination via newsletters, in-services, educational rounds, wall posters and pocket charts	Overall difference between pre- and post intervention slopes was 41 vancomycin units per month *(p=0.01).* Ceftazidime use also decreased post-intervention

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Schouten (2007)[155] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**RCT (clustered)** **Participants:** 1906 patients with CAP or an exacerbation of COPD **Duration:** Pre-intervention: 12 months Post-intervention: 12 months **Setting:** 6 medium to large hospitals (The Netherlands)	Local hospital committee (multidisciplinary composed of a clinical pharmacist, a medical microbiologist, a physician, a pulmonologist, and a quality improvement officer)	**Main:** local opinion leaders to provide education, audit and feedback on 4 indicators. **Supplementary:** Consensus 'critical care pathways' were disseminated to all doctors in pocket versions, PDAs and also accessible on desktops	Guideline adherence for empirical therapy increased from 50.3% to 64.3% in intervention hospitals (IHs) Improved IV to oral switch was observed in IHs (from 78% to 83.6%) and in control hospital (CHs) (53.3% to 71.9%).Broad spectrum to pathogen-directed therapy showed a 5.7% overall improvement in IHs. A moderately positive effect associated with the intervention was detected for the 4 CAP-related indicators.
Senn (2004)[161] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**RCT** **Participants:** 251 patients treated with IV antimicrobials for 3-4 days admitted on surgical and medical wards **Duration:** 5 months **Setting:** 800-bed university hospital (Switzerland)	Undeclared	**Main:** prescribers mailed a questionnaire which asked about possible adaptation of antimicrobials at day 3 or day 4 **Supplementary:** none declared	Impact of questionnaire resulted in 14% reduction in time elapsed until discontinuation or adjustment of antimicrobial therapy (close to statistical significance). Study had a power of 0.41 to demonstrate impact. Attrition bias due to loss of participants from intervention group.
Shojania (1998)[162] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**RCT with nested ITS analysis** Participants: 5536 episodes in 1798 pts Setting: 720-bed university hospital (US)	Undeclared lead	**Main:** computerised reminders at physician order entry and also at 72 hours post-therapy	Orders written by intervention group were less than intervention group (11.3 vs. 16.7; *p=0.04*), fewer pts received vancomycin (7.4 orders vs. 10.3 orders; *p=0.02*) and duration of therapy decreased (26.5 days vs. 41.2 days; *p=0.05*)

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Singh (2000)[131] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**RCT** **Participants:** 81 episodes of care for patients with suspected ventilator-associated pneumonia with a low clinical pulmonary infection scores (CPIS) score **Setting:** single non-teaching hospital (US)	Undeclared	**Main:** study group given ciprofloxacin IV for 3 days with assessment at day 3 based on CPIS and sputum microbiology. **Supplementary:** undeclared	Significant differences in antimicrobials for 3 days (28% vs. 97%), LOS (9.4days vs. 14.7 days; *p=0.04)*, AMR and/or superinfections (15% vs. 35%; *p= 0.02*)
Sirinavin (1998)[123] **GRADE LOE** : $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** unclear **Setting:** a single 900-bed University hospital (Thailand)	ID physician (Consultant)	**Main:** restricted use of ceftazidime, netilmicin, ciprofloxacin, vancomycin and inipenem. Review and recommend change by ID physician **Supplementary:** undeclared	Intervention associated with a significant change in level (-4.04 million baht, *p=0.006*) and a reduction in increase in expenditure over time
Skaer (1993)[148] **GRADE LOE:** 2^{+} (low risk of bias)	**ITS** **Participants:** patients receiving imipenem unclear (post-intervention) **Duration:** 18 months **Setting:** a single non-teaching university hospital (US)	Pharmacists	**Main:** Audit with feedback (review and change or academic detailing program) **Supplementary:** Oral reporting of microbiological data by pharmacists to prescribers	32.7% reduction in antimicrobial usage reported post-intervention.
Solomon (2001)[156] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**RCT** **Participants:** 4500 patients **Setting:** a single 697-bed university hospital (US)	3 Clinical educators 2 ID physicians 1 Pharmacist (Academic detailers)	**Main:** Antimicrobial policy distributed to all doctors and where necessary prescribers were contacted by academic detailers. **Supplementary:** not declared	Mean number of unnecessary days decreased to 5.5 days post-intervention. Multivariate analysis showed the risk for receiving unnecessary prescription reduced by 41% *(p=0.90)*

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Stevenson (1988)[168] **GRADE LOE:** $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** all hospitalised patients **Setting:** single university hospital (UK)	Pharmacist	**Main:** non-restrictive antimicrobial policy implemented **Supplementary:** not declared	Sudden decrease in level by -£6.80 per pt per quarter. However costs rose more rapidly than pre-intervention phase, difference in slope post intervention was +£0.39 per pt per quarter *(p<0.001)*
Suwangool (1991)[114] **GRADE LOE:** $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** all patients admitted to the Department of Medicine **Duration:** **Pre-intervention:** 6 months **Post-intervention:** 12 months **Setting:** a single university hospital (Thailand)	ID physicians in conjunction with a Antimicrobial Management Team (AMT)	**Main:** Written or telephone pre-approval for restricted antimicrobials was required from ID physicians **Supplementary:** Antimicrobial guidelines written by a MDT AMT which consisted of Chairman of Medicine, ID physicians, three physicians from other clinical specialties and a clinical epidemiologist	A sudden decrease in the level of antimicrobial costs by 223.253 Baht per month *(p=0.054)* and a sustained decrease by 51.498 Baht per month *(p=0.07)*. *Nb. Prior to the intervention, there was no trend in antimicrobial costs.*
Talpaert (2011)[173] **GRADE LOE:** $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** DDDs were used to report outcomes **Duration:** Pre-intervention: 12 months Post-intervention: 12 months **Setting:** single university hospital (UK)	Undeclared	**Main:** Revised antimicrobial guidelines which recommended avoiding 'high risk' antimicrobials for CDI such as fluoroquinolones, cephalosporins, clindamycin, and broad spectrum penicillins such as co-amoxiclav **Supplementary**: Removal of targeted antimicrobials from ward stocks	Revised antimicrobial guidelines were associated with significant reduction in the use of cephalosporins and fluoroquinolones i.e.48% and 58.5% respectively. Significant decrease in CDI associated with the intervention [incidence rate ratio (IRR) 0.34; 95%CI 0.20 -0.58, *P<0.0001*] Significant decrease in trend of CDI (post-intervention) [IRR 0.93 -0.99, (0.88 - 0.99), *P* =0.015] but no trend before intervention [IRR 1.00 (0.94 - 1.06), *P = 0.94*]

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Toltzis (1998)[124] **GRADE LOE:** $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** unclear **Setting:** 16-bed paediatric ICU (US)	Undeclared	**Main:** Ceftazidime use restricted to confirmation of microbiology results and other 3rd generation cephalosporins restricted to confirmed or suspected meningitis **Supplementary:** undeclared	Restriction associated with sudden decrease in level by 176.7 doses per month *(p<0.001)* and sustained reduction in slope by 13.4 doses per month *(p=0.012)*
Tolztis (2002)[125] **GRADE LOE:** $1^{+}/1^{-}$ (Medium risk of bias)	**CCT** **Participants:** 1062 neonates with proven or suspected infections caused by Gram -ve bacteria **Duration:** **Setting:** 38-bed neonatal ICU (US)	Unclear	**Main:** Antimicrobial cycling or rotation (monthly), change in policy **Supplementary:** undeclared	No significant changes between study and control group in terms of the incidence of colonisation with multi-resistant Gram -ve bacilli (10.7% vs. 7.7%) and total antimicrobial usage.
Trenholme (1989)[178] **GRADE LOE:** 1^{-} (High risk of bias)	**RCT** **Participants:** 226 pts **Setting:** single hospital (US)	Undeclared	**Main:** Rapid antimicrobial susceptibility testing **Supplementary:** undeclared	Change to therapy was recommended in 64% study vs. 45% control and were followed in 93% study and 78% control (p<0.005)
Tsiata (2001)[104] **GRADE LOE:** 1^{-} (Very high risk of bias)	**RCT (non-blind)** **Participants:** 458 pts admitted to the internal medicine department **Duration:** November 1995 to June 1996 **Setting:** single 600-bed hospital (tertiary care) (Greece)	Undeclared	**Main:** Antimicrobial order forms which require or did not required an authorising signature from a consultant appointed by a nosocomial infectious disease committee **Supplementary:** undeclared	Study design fatally flawed, each group had different numbers of participants and the differences in baseline characteristics indicated unacceptable allocation bias

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
van Kasteran (2005)[159] **GRADE LOE:** $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** patients undergoing surgical procedures **Duration:** Pre-intervention: 6 months Post-intervention: 2 to 9 months (median 6 months) **Setting:** 13 hospitals (The Netherlands)	Infection Control Practitioner	**Main:** Surgical prophylaxis guidelines **Supplementary:** audit and feedback of antimicrobial prophylaxis data and also educational meetings with nurses and medical specialists	Post intervention there was a significant decrease in antimicrobial use which was sustained. Number of DDD/100 procedures decreased from 121 to 79 and AM costs decreased by 25% from €10.96 to €8.24. Overall SSI rates were 5.4% (95%CI:4.3-6.5) pre-intervention and 4.6% (95%CI:3.6-5.4) post-intervention.
Williamsen (2010)[174] **GRADE LOE:** $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** patients prescribed ciprofloxacin (no. of patients was undeclared) **Duration:** 2 years **Setting:** 1370-bed teaching hospital (The Netherlands)	Project manager coordinated consultant microbiologists, pharmacists, pharmacy assistants and medical specialists)	**Main:** Bundle approach consisting of 4 interventions: IV to Oral switch guidelines, antimicrobial guidelines and educational program, restriction of ciprofloxacin and audit and feedback of antimicrobial consumption data **Supplementary:** none declared	A stepwise reduction in IV quinolones use of 71 PDD per month (95%CI: 47 to 95 PDDs/month; *p>0.001*). This resulted in €114,000 over 2 years. The annual cost of the programme was approximately €32,000. However, this was solely based on the salaries of the project coordinator and the pharmacy assistant.
Wilson (1991)[157] **GRADE LOE:** $2^{+}/2^{-}$ (Medium risk of bias)	**ITS** **Participants:** unclear **Setting:** 3 hospitals (UK)	Pharmacist	**Main:** Newsletter prepared by pharmacists and disseminated to all prescribers. Implementation strategies not declared **Supplementary:** not declared	No significant change in level (-0.38, *p=0.559*) or slope (+0.028, *p=0.103*). No change in prescribing observed. *Nb. Use of amoxicillin and amoxicillin and pivamcillin was declining prior to initiation of study.*

STUDY/ LEVEL OF EVIDENCE (LOE)	STUDY DESIGN	INTERVENTION LEAD	INTERVENTIONS	EFFECT(S)/OUTCOME(S)
Wyatt (1998)[158] **GRADE LOE: 1**$^{+}$ (Low risk of bias)	**RCT** **Participants:** 1318 episodes of care in patients **Duration:** 1994 to 1995 **Setting:** 25 non-teaching hospitals (UK)	Obstetrician (local expert)	**Main:** Educational targeted at lead obstetrician and midwife on labour wards at each hospital. **Supplementary:** feedback about current guidelines against Cochrane recommendations	Frequency of administration of antimicrobial prophylaxis increased at both intervention and control hospitals absolute change was greater in control hospitals (20% vs. 8%), this was not significant.
Zanetti (2003)[163] **GRADE LOE: 1**$^{+}$ (Low risk of bias)	**RCT** **Participants**: 331 patients **Duration:** March to June 2000 (4 months) **Setting:** single university hospital (US)	Undeclared lead	**Main:** audible and visual reminder on the operating room console. **Supplementary**: not declared	Intra-operative antimicrobials were administered 63% patients in intervention group compared to 40% in control group.

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APPENDIX III - (Letter of invitation - Study 1)

[Name of pharmacist]
[Address]

[Date]
Dear [Name of pharmacist],
Re: Evaluation of an antimicrobial stewardship questionnaire for NHS Trusts

I am a PhD student at the University of Manchester and I am currently evaluating an antimicrobial stewardship questionnaire for NHS trusts, my supervisors are Professor Jonathan Cooke and Dr Mary Tully. The aims of this study are to investigate whether the current version of the toolkit is representative of the antimicrobial stewardship mechanisms within the NHS and to also examine the usability of the questionnaire. It is envisaged that this questionnaire will be used as a pre-inspection checklist in hospitals.

Participation in this study will involve a single interview which is anticipated to last approximately 60 minutes. **Interviews will be conducted between January 2011 to March 2011.** Participants will be asked to *'think aloud'* or in other words, to verbalise their thoughts as they complete the toolkit. Interviews will be arranged at a time and place convenient for you. The interview will be recorded and all recordings and transcripts will be kept confidential.

I am writing to ask if you would consider participating in this study. If, after reading the participant information leaflet attached, you have any questions, please do not hesitate to contact me. If you are interested, then please fill in the form attached and send it back to me via email. This questionnaire provides me with background information and details so that you can be contacted.

Thank you for your time.

Many thanks,
Chantelle Bailey
PhD Research Student

MANCHESTER 1824

The University of Manchester

APPENDIX IV - (Participant Information Leaflet- Study 1)

Evaluation of an antimicrobial stewardship questionnaire for NHS Trusts Participant Information Leaflet

Introduction

You are being invited to take part in the above study. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information and discuss it with others if you wish. The information provided below will hopefully give you a good understanding of what the research is about and how you might be able to help. However, if you have any other questions or clarifications, please do not hesitate to contact me on the telephone number or email address given below. Please take time to decide whether or not you wish to take part.
Nb. If you have used the ASAT previously, you would be unable to take part in this study.

What is the purpose of the study?

The questionnaire has been developed to monitor and measure the antimicrobial stewardship mechanisms in NHS hospitals. The research aims to identify whether the content of the toolkit is representative of antimicrobial stewardship mechanisms in NHS trusts and also to gather data on the usability of the toolkit. It is hoped that, through this research, the knowledge gained about antimicrobial stewardship practices in NHS trusts could be used to inform the future development of the questionnaire.

Why have I been chosen?

Antimicrobial pharmacists or pharmacist with antimicrobial duties have antimicrobial stewardship as part of the job description so therefore there is viewed as the best data source on antimicrobial stewardship within their hospitals. You have been chosen as you are an antimicrobial pharmacist or a pharmacist with antimicrobial duties.

What will happen to me if I decide to take part?

If you decide to take part in this study you may be asked to participate in a single interview. This interview will be conducted at a time and place suitable for you. During the interview you will be asked to 'think aloud', or verbalise your thoughts as you complete the toolkit. It is estimated that the interview should take about an hour. No specific colleague or patient information is needed during the interview. The interview will be audio-recorded with your permission; if you object, then I will just take notes. You may request that the audio-recorder to be turned off or to stop the interview at any point. Direct quotations may be used for the purposes of disseminating the research findings, but in such a way as not to identify you. The audio-recordings will be stored securely and anonymised. The audio-recordings will be destroyed at the end of the study.
It is expected you will benefit from the process of reflection involved in the study. A summary of research findings will be available on request.

Do I have to take part?

No, participation is entirely voluntary.

Will the information about me remain confidential?

All information obtained from the interview and any other contact with you will be kept confidential. Other than my supervisors, your participation in the study will not be divulged to any person. If any identifying information is mentioned it will be removed from the interview data.

What do I do next?

If you decide you may like to take part then please complete the attached form. This form provides me with information about your post and also your contact details so that I can send you further information. It does not mean that you are agreeing to take part in this study and you may decline any further involvement at a later stage. It is possible that you may not be selected for the study and if this is the case then we will let you know by letter that no further participation is required. In this case your personal details will be destroyed.

What if there is a problem?

If, after taking part in this research, you are unhappy with any aspect of the process you contact my supervisors or myself (see contact details below).

Thank you for your time

Chantelle Bailey MSc
Email: chantelle.bailey-2@postgrad.manchester.ac.uk
Tel: 0161 275 8363
1st Floor, Stopford Building
School of Pharmacy and Pharmaceutical Sciences
University of Manchester
Manchester
M13 9PT

If you need further information please do not hesitate to contact me or if you would rather talk to my supervisors about this project please feel free to do so.

Professor Jonathan Cooke: 0161 291 4195 or email: jonathan.cooke@manchester.ac.uk
Dr Mary Tully: 0161 275 4242 or email:
mary.p.tully@manchester.ac.uk

APPENDIX V (Participant Questionnaire - Study1)

Evaluation of an antimicrobial stewardship questionnaire for NHS Trusts

If you would be willing to participate in this research please fill in the form below. The details you provide on this form will be used to select participants for interview. This form does not assume that you are consenting to the research and a further consent form will need to be signed before an interview is conducted. The information you provide on this form is strictly confidential.

Please indicate below which best describes your current job role:

Antimicrobial Pharmacist	**Yes** □	**No** □
Pharmacist with antimicrobial duties	**Yes** □	**No** □

Thank you for taking time to fill in the questionnaire
Please return the questionnaire via email to
chantelle.bailey-2@postgrad.manchester.ac.uk

APPENDIX VI (Confirmation letter - Study 1)

Chantelle Bailey,
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Tel: +44 (0)161 275 8363
chantelle.bailey-2@postgrad.manchester.ac.uk

[Name of pharmacist]
[Address]

[Date]

Dear [Name of pharmacist],

Re: Evaluation of an antimicrobial stewardship questionnaire for NHS Trusts

Thank you for participating in the above study. I am writing to confirm our telephone conversation regarding our arrangements to meet at [location, date and time].

As previously mentioned, this study will involve a one hour interview that will be audio recorded with your permission. During the interview you will be asked to verbalise your thoughts as you complete that antimicrobial stewardship toolkit. Your participation in this interview is voluntary and you may discontinue your participation at anytime.

I have included in this letter another copy of the participant information leaflet for your convenience. Also included is a consent form, which needs to be read and signed. This form will be collected before the interview commences.

In the meantime, if you have any questions please do not hesitate to contact me on the above details.

Again, I would like to thank you for participating in this research study.

Yours sincerely,
Chantelle Bailey,
PhD Research Student

APPENDIX VII (Consent form-Study 1)

CONSENT FORM

Evaluation of an antimicrobial stewardship questionnaire for NHS Trusts

	Please initial box
I have read the information leaflet and have had the opportunity to ask any questions I may have had.	
I have received a satisfactory response to any questions I have asked	
I agree for the interview to be audio-recorded	
I do not agree for my interview to be audio-recorded but I do agree that the interviewer can take notes of my interview	
I understand that I do not need to participate in the study and if I participate I am free to withdraw at any time without giving a reason	
I agree for anonymised quotations from my interview to be used for the purposes of disseminating the results	
I agree to take part in the study	

Signed:.....
Print:.....
Date: .....

Chantelle Bailey – Researcher
Signed:.....
Date: .....

APPENDIX VIII (Thank you letter-Study 1)

Chantelle Bailey,
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Oxford Road,
M13 9PT.
Tel: +44 (0)161 275 8363
chantelle.bailey-2@postgrad.manchester.ac.uk

[Name of pharmacist]
[Address]

[Date]

Dear [Name of pharmacist],

Re: Evaluation of an antimicrobial stewardship questionnaire for NHS Trusts

Dear [Name of Pharmacist],
I would like to thank you for participating in this study. The data obtained from these interviews will help the development of the antimicrobial stewardship toolkit.
The information obtained in this study maybe published in scientific journals or presented at scientific meetings; however your identity will be kept strictly confidential.
If you have any queries about the study, please do not hesitate to contact me.
Again, I would like to thank you for participating in this study.

Yours sincerely,
Chantelle Bailey,
PhD Research Student

APPENDIX IX (Interview Protocol-Study 1)

INTERVIEW SCHEDULE

The purpose of the interviews to gather data on the cognitive processes respondents undergo in determining the answers to the questions of the ASAT. Any ambiguities and/or difficulties which the respondent encounter when completing the ASAT will be recorded. This type of interview is mainly concerned with the cognitive processes the respondents use to answer the questions as opposed to the answers to the questions themselves. It is hoped that the data obtained from this interview will inform subsequent revisions of the ASAT, if necessary.

Please be assured that the information gathered from these interviews will be treated with strict confidentiality. Any details that could potentially identify or recognise a patient, staff member, you or your trust will be subsequently removed from the interview transcripts.

The interview will be conducted in four parts:

Part 1: Pre-interview (‘*Think aloud’* exercise)

Part 2: Cognitive interview (ASAT)

Part 3: ASAT Assessment

Part 4: Conclusion

The interview will last approximately 60 minutes which includes a very short training exercise on *‘thinking aloud’*.

The interview will be recorded with your consent. The recordings will be kept securely for a period of time and then destroyed.

Do you have any questions before starting the interview?

PART 1: Thinking aloud exercise (Think Aloud training exercise)

‘*Try to visualise the place where you live, and think about how many windows there are in that place. As you count up, tell me what you are seeing and thinking about*’

PART 2: Cognitive interview (ASAT)

The ASAT contains 83 questions, so I will ask you each question and I would like to ‘think aloud’ as you answer each question.

For example, Question 1.1 *‘Does the trust have a written strategy for assuring the quality of antimicrobial use?’*

Participant's response

Both pre-prepared and spontaneous probes will be used to obtained in-depth information and to explore participant's responses, where indicated. The probe used will be dependent on the responses given by the participant.

<u>Pre-prepared probes</u>

Probes (General)

- How did you go about answering that question?
- How did you arrive at that answer?
- What went through your mind when you were asked that question?
- Can you tell me what you were thinking when you were looking at this?
- Was that difficult or easy to answer? Why was that?
- In your opinion, are the response categories set out with this question appropriate? If not, what alternative would you use?
- Would you choose to keep this question in the ASAT, remove it or replace it with another question? If you were to replace it , what would you replace it with?

Probes (Paraphrasing)

- What would you say that question was asking of you?
- How would you say that question?
- Can you repeat that question in your words?

Probes (Cognitive steps)

Comprehension

- What does '_____' mean to you?
- What, to you, is '_____'?
- In your own words, what is '_____'?

Judgment/Recall

- How would you remember that?
- What brought that to mind?
- How did you work that out?
- What time period were you thinking of? (From when to when?) reference time period
- What did you think of as you tried to remember '_____'?
- Did you try to count each time you [did X], or did you make an estimate?

Confidence Judgement

- How well do you remember this?
- How sure are you of your answer?

<u>Spontaneous probes</u>

Observation - based probes

- I noticed you were spending some time with that question, can you tell me what you were thinking about?
- I noticed that you hesitated before you answered, can you tell me what you were thinking?
- You answered that question very quickly, why was that?

Listening based probes

- Why do you say that?
- Can you tell me a bit more about that?

PART 3: ASAT assessment

Participants will be asked to comment on the ASAT in terms of length of the ASAT, ASAT layout, ease of use, question flow, any domain and/or question omissions (if any), relevance to the topic or domains of the ASAT, overall instrument design features and overall satisfaction with the ASAT.

Main question: **'What is your overall opinion of the ASAT?'**

The following probes may be asked:

- *What do you think of the length of the ASAT?*
- *Are there any issues specific to antimicrobial stewardship that is missing from the ASAT?*
- *Did you find the ASAT easy to use?*
- *What do think of the layout of the ASAT?*
- *Do you have any additional comments?*

PART 4: Conclusion of the interview

Thank you very much for participating in this study. The interview has been very valuable to this research study. If you like a copy of the interview transcript please let me know and I will send a copy to you. On completion of the study a summary of the findings will be sent to you if wish. Please feel free to contact me if you have any questions or issues to discuss regarding the study.

Switch the digital recorder off

POST INTERVIEW

A thank you letter will be sent to the participant.

APPENDIX XI - Ethics Approval (Study 1 to Study 3)

RESEARCH ETHICS APPROVAL (STUDY 1)

From: Brown Laura (NHSNW) [Laura.Brown@northwest.nhs.uk]
Sent: 02 December 2010 14:06
To: chantelle.bailey-2@postgrad.manchester.ac.uk
Subject: PhD Project (ethics)

Dear Chantelle,
The Chair of Manchester Central REC has looked at your proposal.
In the opinion of the Chair this proposal falls into the category of service development / evaluation and formal NHS ethical review is not required.
Kind regards,
Laura

Laura Brown | Assistant Co-ordinator

North West 7 Research Ethics Committee - Greater Manchester Central
North West 8 Research Ethics Committee- Greater Manchester East
Direct line 0161 625 7831 | Line 2 0161 625 7825 | Line 3 0161 625 7820

3rd Floor, Barlow House, 4 Minshull Street, Manchester M1 3DZ
Email: Laura.Brown@northwest.nhs.uk | www.nres.npsa.nhs.uk

Streamline your research application process with IRAS (Integrated Research Application System): www.myresearchproject.org.uk
If your e-mail is regarding a formal request for information under the Freedom of Information Act, please re-send to foi@npsa.nhs.uk to ensure that it is dealt with promptly.

From: Hutchings Elaine (NHSNW) [Elaine.Hutchings@northwest.nhs.uk]
Sent: 02 December 2010 12:24
To: Chantelle Bailey
Subject: RE: PhD project (Ethics)

Dear Chantelle,

Your proposal has been passed to the Chair of North West 7 Research Ethics Committee - Greater Manchester Central for an opinion and the Assistant Co-ordinator for the Committee, Laura Brown, will contact you when she receives his reply.

Kind regards,
Elaine

Elaine Hutchings
Co-ordinator, Northwest 6 REC - GM South
Northwest 8 REC - GM East
3rd Floor, Barlow House
Minshull Street
Manchester
M1 3DZ

Tel: 0161 625 7820

RESEARCH ETHICS APPROVAL (STUDY 2)

From: Hutchings Elaine (NHSNW) [Elaine.Hutchings@northwest.nhs.uk]
Sent: 02 June 2011 13:06
To: Chantelle Bailey
Subject: RE: PhD project ethics (Study 2)

Dear Chantelle

Apologies for the delay with this.

I sent your query to the Chair of NRES Committee North West - Greater Manchester West, and she has advised that in her view, the project is service evaluation and not research, and therefore does not require ethical review.

Best wishes,
Elaine

Elaine Hutchings
Co-ordinator, NRES Committee North West - Greater Manchester South
NRES Committee North West - Greater Manchester East
3rd Floor, Barlow House
Minshull Street
Manchester
M1 3DZ

Tel: 0161 625 7820

RESEARCH ETHICS APPROVAL (STUDY 3)

From: Catherine Birch
Sent: 22 September 2011 11:09
To: Rachel Georgiou; Chantelle Bailey
Cc: Maureen Daniels
Subject: RE: Research Ethics (Study 3)

Hi Chantelle

I have read your proposal and I agree with Rachel that this is not research requiring REC review. We can issue notification only approval which is an acknowledgement that R&D have reviewed your project and do not consider it to require REC and R&D approval. In order for us to do this we would need evidence that it has undergone University ethics review and that the relevant permissions have been sought within the services.

Best Wishes
Catherine

Catherine Birch
Research & Development Support Officer
Research and Development Department
NHS SalfoR+D
Summerfield House
Salford Royal NHS Foundation Trust
Stott Lane
Salford
M6 8HD
Tel: 0161 206 4447

From: Rachel Georgiou
Sent: 19 September 2011 07:37
To: Chantelle Bailey
Cc: Catherine Birch
Subject: RE: Research Ethics (Study 3)

Hi Chantelle
Sorry for the delay in responding. I'm not sure if anyone else has responded to this. I do not think this requires NHS REC review. It should however have a review by the University's ethics committee. Catherine, please can you have a look at this? I'm not sure whether this would be classed as research.

Chantelle, if Catherine confirms my opinion, then you will not need R and D approval, but will need permission from the individual services concerned.

With best wishes,

Rachel

Chantelle Bailey,
School of Pharmacy and Pharmaceutical Sciences,
Faculty of Human and Medical Sciences,
The University of Manchester,
Oxford Road,
M13 9PT.
Tel: +44 (0)161 275 8363
chantelle.bailey-2@postgrad.manchester.ac.uk

APPENDIX XII (Letter of invitation - Study 2)

[Name of clinical microbiologist]
[Address]
[Date]
Dear [Name of clinical microbiologist],

Re: Perspectives of clinical microbiologists on antimicrobial stewardship in NHS Trusts

I am a PhD student at the University of Manchester and I am currently evaluating an antimicrobial stewardship questionnaire for NHS trusts. My supervisors are Professor Jonathan Cooke and Dr Mary Tully. The aims of this study are to investigate whether the current version of the questionnaire is representative of the antimicrobial stewardship programmes within the NHS.

The questionnaire primarily focuses on antimicrobial stewardship however the role of clinical microbiologists for example, involvement the development of antimicrobial policies has not been fully represented in the present version of the questionnaire. I would like to investigate your role in antimicrobial stewardship programmes. It is hoped that through this research that the role of clinical microbiology would be further elucidated and the findings used to update the questionnaire. A copy of the current version of the questionnaire is attached.

Participation in this study will involve a single interview which is anticipated to last up to 60 minutes. **Interviews will be conducted between June 2011 to July 2011.** Participants will be asked to talk about their roles and responsibilities in antimicrobial stewardship within their trust. Also, they will be asked to comment on the content of the questionnaire. Interviews will be arranged at a time and place convenient for you. The interview will be recorded and all recordings and transcripts will be kept confidential.

I am writing to ask if you would consider participating in this study. If, after reading the participant information leaflet attached, you have any questions, please do not hesitate to contact me. If you are interested, then please fill in the form attached and send it back to me via email. This questionnaire provides me with background information and details so that you can be contacted.

Thank you for your time.

Chantelle Bailey
PhD Research Student

APPENDIX XIII (Participant Information Leaflet-Study 2)

Perspectives of clinical microbiologists on antimicrobial stewardship in NHS Trusts
Participant Information Leaflet

Introduction
You are being invited to take part in the above study. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information and discuss it with others if you wish. The information provided below will hopefully give you a good understanding of what the research is about and how you might be able to help. However, if you have any other questions or clarifications, please do not hesitate to contact me on the telephone number or email address given below. Please take time to decide whether or not you wish to take part.

What is the purpose of the study?
The questionnaire has been developed to monitor and measure the antimicrobial stewardship mechanisms in NHS hospitals. The aims of this study are to investigate whether the current version of the questionnaire is representative of the antimicrobial stewardship mechanisms within the NHS. The questionnaire currently focuses on the role of pharmacists in antimicrobial stewardship however the role of clinical microbiologists has not been fully addressed. I would like to investigate your role in antimicrobial stewardship. It is hoped that through this research that the role of clinical microbiology would be further elucidated and the findings used to update the questionnaire.

Why have I been chosen?
Clinical microbiologists have antimicrobial stewardship as part of the job description so therefore there is viewed as one of the best data sources on antimicrobial stewardship within their hospitals. You have been chosen as you are a clinical microbiologist.

What will happen to me if I decide to take part?
If you decide to take part in this study you will be sent a copy of the antimicrobial stewardship questionnaire. You will be asked to participate in a single interview. This interview will be conducted at a time and place suitable for you. During the interview you will be asked to talk about your roles and responsibilities in antimicrobial stewardship programmes within your trust. Also, you will be asked to comment on the content of the questionnaire. It is estimated that the interview should take no longer than 60 minutes. No specific colleague or patient information is needed during the interview. The interview will be audio-recorded with your permission; if you object, then I will just take notes. You may request that the audio-recorder to be turned off or to stop the interview at any point. Direct quotations may be used for the purposes of disseminating the research findings, but in such a way as not to identify you. The audio-recordings will be stored securely and anonymised. The audio-recordings will be destroyed at the end of the study.

Are there any risks or benefits to taking part?
It is expected you will benefit from the process of reflection involved in the study. A summary of research findings will be available on request.

Do I have to take part?
No, participation is entirely voluntary.

Will the information about me remain confidential?

All information obtained from the interview and any other contact with you will be kept confidential. Other than my supervisors, your participation in the study will not be divulged to any person. If any identifying information is mentioned it will be removed from the interview data.

What do I do next?

If you decide you may like to take part then please complete the attached form. This form provides me with information about your post and also your contact details so that I can send you further information. It does not mean that you are agreeing to take part in this study and you may decline any further involvement at a later stage. It is possible that you may not be selected for the study and if this is the case then we will let you know by letter that no further participation is required. In this case your personal details will be destroyed.

What if there is a problem?

If, after taking part in this research, you are unhappy with any aspect of the process you contact my supervisors or myself (see contact details below).

Thank you for your time

Chantelle Bailey MSc
Email: chantelle.bailey-2@postgrad.manchester.ac.uk
Tel: 0161 275 8363
1st Floor, Stopford Building
School of Pharmacy and Pharmaceutical Sciences
University of Manchester
Manchester
M13 9PT

If you need further information please do not hesitate to contact me or if you would rather talk to my supervisors about this project please feel free to do so.

Professor Jonathan Cooke: 0161 291 4195 or email: jonathan.cooke@manchester.ac.uk
Dr Mary Tully: 0161 275 4242 or email: mary.p.tully@manchester.ac.uk

APPENDIX XIV (Participant questionnaire-Study 2)

Perspectives of clinical microbiologists on antimicrobial stewardship in NHS Trusts

If you would be willing to participate in this research please fill in the form below. The details you provide on this form will be used to select participants for interview. This form does not assume that you are consenting to the research and a further consent form will need to be signed before an interview is conducted. The information you provide on this form is strictly confidential.
Please indicate below which best describes your current job role:

Clinical Microbiologist (involved with antimicrobial stewardship programmes	**Yes** □	**No** □
Clinical Microbiologist (not involved with antimicrobial stewardship programmes	**Yes** □	**No** □

Thank you for taking time to fill in the questionnaire
Please return the questionnaire via email to

chantelle.bailey-2@postgrad.manchester.ac.uk

APPENDIX XV (Confirmation letter-Study 2)

Chantelle Bailey,
School of Pharmacy and Pharmaceutical Sciences,
Faculty of Human and Medical Sciences,
The University of Manchester,
Oxford Road,
M13 9PT.
Tel: +44 (0)161 275 8363
chantelle.bailey-2@postgrad.manchester.ac.uk

[Name of clinical microbiologist]
[Address]

[Date]
Dear [Name of clinical microbiologist],

Re: Perspectives of clinical microbiologists on antimicrobial stewardship in NHS Trusts

Thank you for participating in the above study. I am writing to confirm our telephone conversation regarding our arrangements to meet at [location, date and time].

As previously mentioned, this study will involve a one hour interview that will be audio recorded with your permission. During the interview you will be asked to discuss you role and responsibilities in antimicrobial stewardship within your trust and also comment on the content of the questionnaire. A copy of the questionnaire is attached for your perusal. Your participation in this interview is voluntary and you may discontinue your participation at anytime.

I have included in this letter another copy of the participant information leaflet for your convenience. Also included is a consent form, which needs to be read and signed. This form will be collected before the interview commences.

In the meantime, if you have any questions please do not hesitate to contact me on the above details.

Again, I would like to thank you for participating in this research study.

Yours sincerely,
Chantelle Bailey,
PhD Research Student

APPENDIX XVI (Consent form-Study 2)

CONSENT FORM

Perspectives of clinical microbiologists on antimicrobial stewardship in NHS Trusts

	Please initial box
I have read the information leaflet and have had the opportunity to ask any questions I may have had.	
I have received a satisfactory response to any questions I have asked	
I agree for the interview to be audio-recorded	
I do not agree for my interview to be audio-recorded but I do agree that the interviewer can take notes of my interview	
I understand that I do not need to participate in the study and if I participate I am free to withdraw at any time without giving a reason	
I agree for anonymised quotations from my interview to be used for the purposes of disseminating the results	
I agree to take part in the study	

Signed:.....
Print:.....
Date: .....
Chantelle Bailey – Researcher
Signed:.....
Date: .....

Chantelle Bailey,
School of Pharmacy and Pharmaceutical Sciences,
Faculty of Human and Medical Sciences,
The University of Manchester,
Oxford Road,
M13 9PT.
Tel: +44 (0)161 275 8363
chantelle.bailey-2@postgrad.manchester.ac.uk

APPENDIX XVII (Thank you letter-Study 2)
[Name of clinical microbiologist]
[Address]

[Date]

Dear [Name of clinical microbiologist],

Re: Perspectives of clinical microbiologists on antimicrobial stewardship in NHS Trusts

I would like to thank you for participating in this study. The data obtained from these interviews will help the development of the antimicrobial stewardship questionnaire. The information obtained in this study maybe published in scientific journals or presented at scientific meetings; however your identity will be kept strictly confidential. If you have any queries about the study, please do not hesitate to contact me.
Again, I would like to thank you for participating in this study.

Yours sincerely,
Chantelle Bailey,
PhD Research Student

APPENDIX XVIII (INTERVIEW SCHEDULE - Study 2)

The purpose of this interview is to gather data on the role and responsibilities of clinical microbiologists in antimicrobial stewardship in hospitals. Also, you will be asked to comment on the content of the antimicrobial stewardship questionnaire. This questionnaire primarily focuses on the role of pharmacists in antimicrobial stewardship. The interview will be semi-structured, in other words I will ask you a series of open-ended questions which will give you time and scope to discuss your role. It is hoped that the data obtained from this interview will inform subsequent revisions of the questionnaire where required.

Please be assured that the information gathered from these interviews will be treated with strict confidentiality. Any details that could potentially identify or recognise a patient, staff member, you or your trust will be subsequently removed from the interview transcripts.

It is anticipated that the interview will last for up to 60 minutes and it will be recorded unless you have indicated otherwise.

Do you have any questions before we start the interview?

Switch the digital recorder on

The interview will be conducted in three parts:

Part 1: Cognitive interview

Part 2: Role and responsibilities of the clinical microbiologists in antimicrobial stewardship

Part 3: Assessment of the antimicrobial stewardship questionnaire

Part 4: Conclusion

Part 1: Cognitive interview

- Thinking aloud exercise

'*Try to visualise the place where you live, and think about how many windows there are in that place. As you count up, tell me what you are seeing and thinking about*'

The following questions will be used during the cognitive interview section of the interview:

- *Is there a clinical microbiologist on your hospital's antimicrobial stewardship committee?*
- *Are clinical microbiologists within your hospital involved in the development of AM policies?*
- *Are antimicrobial resistance trends used to inform the content of AM policies and guidelines?*
- *Are clinical microbiologists within your hospital in the development of AM formularies?*
- *Are clinical microbiologists involved on ward rounds?*
- *Is the reporting of antimicrobial susceptibility testing results in line with formulary choices?*
- *Is your hospital actively involved in surveillance or monitoring of antimicrobial resistance trends?*

For example, '*Is there a clinical microbiologist on your hospital's antimicrobial stewardship committee?*

Participant's response

Both pre-prepared and spontaneous probes will be used to obtained in-depth information and to explore participant's responses, where indicated. The probe used will be dependent on the responses given by the participant.

<u>Pre-prepared probes</u>

Probes (General)

- How did you go about answering that question?
- How did you arrive at that answer?

- What went through your mind when you were asked that question?
- Can you tell me what you were thinking when you were looking at this?
- Was that difficult or easy to answer? Why was that?
- In your opinion, are the response categories set out with this question appropriate? If not, what alternative would you use?
- Would you choose to keep this question in the ASAT, remove it or replace it with another question? If you were to replace it , what would you replace it with?

Probes (Paraphrasing)

- What would you say that question was asking of you?
- How would you say that question?
- Can you repeat that question in your words?

Probes (Cognitive steps)

Comprehension

- What does '_____' mean to you?
- What, to you, is '_____'?
- In your own words, what is '_____'?

Judgment/Recall

- How would you remember that?
- What brought that to mind?
- How did you work that out?
- What time period were you thinking of? (From when to when?) reference time period
- What did you think of as you tried to remember '_____'?
- Did you try to count each time you [did X], or did you make an estimate?

Confidence Judgement

- How well do you remember this?
- How sure are you of your answer?

Spontaneous probes

Observation - based probes

- I noticed you were spending some time with that question, can you tell me what you were thinking about?
- I noticed that you hesitated before you answered, can you tell me what you were thinking?
- You answered that question very quickly, why was that?

Listening based probes

- Why do you say that?
- Can you tell me a bit more about that?

Part 2: Role and responsibilities of clinical microbiologists in antimicrobial stewardship programmes

- Give an overview of your background that is relevant to this role?
  Probe:
  - ⇒ *How long have you been in post?*
  - ⇒ *Have you worked in different types of hospitals e.g. specialist care?*

- Are there any clinical guidelines and/or clinical guidance that underpin your role?
  - ⇒ *What is your understanding of the role of clinical guidelines and/or clinical guidance in your role?*
  - ⇒ *In your opinion, which guidelines are the most important to you in your day to day activities?*

- What is your understanding of the antimicrobial stewardship programme within your hospital?
  - ⇒ *In your opinion, what is your role in antimicrobial stewardship programmes?*
  - ⇒ *In your opinion,* what has helped your hospital's antimicrobial stewardship programme?
  - ⇒ *In your opinion,* are there any barriers to your hospital's antimicrobial stewardship programme?
  - ⇒ *How have you addressed these barriers?*
  - ⇒ *In your opinion, is there anything that can be done to improve the antimicrobial stewardship programme in your hospital?*

PART 3: Assessment of the antimicrobial stewardship questionnaire

You have been previously sent the antimicrobial stewardship questionnaire for your perusal so that you were able to assess the questionnaire's coverage of the role of clinical microbiologists in antimicrobial stewardship programmes.

- *In your opinion, does it cover all areas of your hospital's antimicrobial stewardship programmes?*
- *What do you think of the coverage of the role of clinical microbiologists in the questionnaire?*
- *In your opinion, are there any adjustments required to the content of the questionnaire*?

Participants will be asked to comment on the questionnaire in terms of length of the questionnaire, questionnaire layout, ease of use, question flow, any domain and/or question omissions (if any), relevance to the topic or domains of the questionnaire, overall instrument design features and overall satisfaction with the questionnaire.

Main question: **'What is your overall opinion of the questionnaire?'**

The following probes may be asked:

- *What do you think of the length of the* questionnaire*?*
- *Are there any issues specific to antimicrobial stewardship that is missing from the* questionnaire*?*
- *Did you find the* questionnaire *easy to use?*
- *What do think of the layout of the* questionnaire*?*
- *Do you have any additional comments?*

PART 4: Conclusion of the interview

Thank you very much for participating in this study. The interview has been very valuable to this research study. If you like a copy of the interview transcript please let me know and I will send a copy to you. On completion of the study a summary of the findings will be sent to you if wish. Please feel free to contact me if you have any questions or issues to discuss regarding the study.

Switch the digital recorder off

<u>POST INTERVIEW</u>

A thank you letter will be sent to the participant.

APPENDIX XX (Letter of invitation - Study 3)
[Name of participant]
[Address]
[Date]
Dear [Name of participant],

Chantelle Bailey,
School of Pharmacy and Pharmaceutical Sciences,
Faculty of Human and Medical Sciences,
The University of Manchester,
Oxford Road,
M13 9PT.
Tel: +44 (0)161 275 8363
chantelle.bailey-2@postgrad.manchester.ac.uk

Re: Evaluation of the antimicrobial stewardship questionnaire

I am a PhD student at the University of Manchester and I am currently evaluating an antimicrobial stewardship questionnaire for NHS trusts. My supervisors are Professor Jonathan Cooke and Dr Mary Tully. The aims of this study are to investigate the validity of the current version of the antimicrobial stewardship programmes within the NHS.

The questionnaire primarily focuses on the processes utilised by NHS hospitals, to develop their antimicrobial stewardship programmes which promote prudent antimicrobial prescribing within their organisations. The questionnaire has been through several iterations. Each modification was informed by feedback from antimicrobial pharmacists and clinical microbiologists, who were involved in antimicrobial stewardship programmes. This aim of this current study is to investigate the validity of the questionnaire. A copy of the current version of the questionnaire is attached.

Participation in this study will involve completion and submission of the questionnaire to the researcher. **Data collection will be conducted between December 2011 to January 2012.** Also, you will be asked to provide general feedback on the usability of the questionnaire. The data collected from the questionnaire about your hospital's antimicrobial stewardship programmes and any feedback will be kept strictly confidential.

I am writing to ask if you would consider participating in this study. If, after reading the participant information leaflet attached, you have any questions, please do not hesitate to contact me. If you are interested, then please fill in the form attached and send it back to me via email. This questionnaire provides me with background information and details so that you can be contacted.

Thank you for your time.

Chantelle Bailey
PhD Research Student

MANCHESTER 1824

The University of Manchester

APPENDIX XXI (Participant Information Leaflet-Study 3)

Evaluation of the antimicrobial stewardship questionnaire
Participant Information Leaflet

Introduction

You are being invited to take part in the above study. Before you decide whether or not to take part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information and discuss it with others if you wish. The information provided below will hopefully give you a good understanding of what the research is about and how you might be able to help. However, if you have any other questions or clarifications, please do not hesitate to contact me on the telephone number or email address given below. Please take time to decide whether or not you wish to take part.

What is the purpose of the study?

The questionnaire has been developed to monitor and measure the antimicrobial stewardship mechanisms in NHS hospitals. The aims of this study are to investigate the validity of the current version of the questionnaire and to ensure that it is representative of the antimicrobial stewardship mechanisms within the NHS. It is hoped that through this research that the questionnaire would be further developed to ensure that it is effective at evaluating antimicrobial stewardship programmes in NHS hospitals.

Why have I been chosen?

Antimicrobial pharmacists and clinical microbiologists have antimicrobial stewardship as part of their job descriptions or job plans therefore you are viewed as one of the best data sources on antimicrobial stewardship within their hospitals. You have been chosen as you are either an antimicrobial pharmacists or a clinical microbiologist.

What will happen to me if I decide to take part?

If you decide to take part in this study you will be asked to complete the current version antimicrobial stewardship questionnaire. Where you are unsure of a response to a question, please feel free to consult with other members of staff. After completing the questionnaire, you should return it to the researcher for analysis. Also, you will be asked to comment on the content of the questionnaire. No specific colleague or patient information is needed on the questionnaire. The data obtained from the questionnaires will be stored securely and anonymised. The questionnaires will be destroyed at the end of the study.

Are there any risks or benefits to taking part?

It is expected you will benefit from the process of reflection involved in the study. A summary of research findings will be available on request.

Do I have to take part?

No, participation is entirely voluntary.

Will the information about me remain confidential?
All information obtained from the questionnaire and any other contact with you will be kept confidential. Other than my supervisors, your, or your hospitals, participation in the study will not be divulged to any person.

What do I do next?
If you decide you would like to take part then please complete the attached form. This form provides me with information about your post and also your contact details so that I can send you further information. It does not mean that you are agreeing to take part in this study and you may decline any further involvement at a later stage.

What if there is a problem?
If, after taking part in this research, you are unhappy with any aspect of the process you contact my supervisors or myself (see contact details below).

Thank you for your time

Chantelle Bailey MSc
Email: chantelle.bailey-2@postgrad.manchester.ac.uk
Tel: 0161 275 8363
1st Floor, Stopford Building
School of Pharmacy and Pharmaceutical Sciences
University of Manchester
Manchester
M13 9PT

If you need further information please do not hesitate to contact me or if you would rather talk to my supervisors about this project please feel free to do so.

Professor Jonathan Cooke: 0161 275 2342 or email: jonathan.cooke@manchester.ac.uk
Dr Mary Tully: 0161 275 4242 or email: mary.p.tully@manchester.ac.uk

Chantelle Bailey,
School of Pharmacy and Pharmaceutical Sciences,
Faculty of Human and Medical Sciences,
The University of Manchester,
Oxford Road,
M13 9PT.
Tel: +44 (0)161 275 8363
chantelle.bailey-2@postgrad.manchester.ac.uk

APPENDIX XXII (Confirmation letter - Study 3)

[Name of participant]
[Address]
[Date]
Dear [Name of participant],

Re: Evaluation of the antimicrobial stewardship questionnaire

Thank you for participating in the above study. This study will involve a single submission of the completed antimicrobial stewardship questionnaire. A copy of the questionnaire is attached for your perusal. Your participation in this study is voluntary.
I have included in this letter another copy of the participant information leaflet for your convenience. In the meantime, if you have any questions please do not hesitate to contact me on the above details.
Again, I would like to thank you for participating in this research study.

Yours sincerely,

……
Chantelle Bailey,
PhD Research Student

Chantelle Bailey,
School of Pharmacy and Pharmaceutical Sciences,
Faculty of Human and Medical Sciences,
The University of Manchester,
Oxford Road,
M13 9PT.
Tel: +44 (0)161 275 8363
chantelle.bailey-2@postgrad.manchester.ac.uk

APPENDIX XXIII (Thank you letter - Study 3)
[Name of participant]
[Address]
[Date]

Dear [Name of participant],

Re: Evaluation of the antimicrobial stewardship questionnaire

I would like to thank you for participating in this study. The data obtained from these data submissions will help the development of the antimicrobial stewardship questionnaire.

The information obtained in this study maybe published in scientific journals or presented at scientific meetings however you and your hospital's identity will be kept strictly confidential.

If you have any queries about the study, please do not hesitate to contact me.

Again, I would like to thank you for participating in this study.

Yours sincerely,

Chantelle Bailey,
PhD Research Student

APPENDIX XXIV - Modifications Table (ASAT v15a to ASAT v16)

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
1.1	**Comprehension - lexical**	**Action:** definition for 'strategy' included in glossary for ASAT v16 **Action:** change *'antimicrobial use'* to *'antimicrobial stewardship'* and provide a definition for antimicrobial stewardship in glossary for ASAT v16	**Original question:** Does the Trust have a written strategy for assuring the quality of antimicrobial use? **Modified question:** Does the Trust have a written *strategy** for ensuring high quality *antimicrobial stewardship**?
Rationale for retention: The written antimicrobial strategy refers to a 1 yr, 3 yr or a 5 yr for assuring AMS. This document could include guidance on the guideline development, frequency of guideline or policy review, education strategy, and clinical audit strategy. It was felt that it was important that NHS trusts have a document that contains the operation strategy for assuring high quality antimicrobial stewardship for the trust. **Supporting guidelines**: **H&SC (2008):** Criterion 1: Section 1.1; p.10, Criterion 10: Section 10.1, p.36; **SACAR AM Framework:** Section 4.1, Section 4.4; **Medicines Management in NHS Trusts:** Standard 1, p.4			
1.2	**No modifications were made to this question**	N/A	N/A
Rationale for retention: No concerns were raised by respondents about Q1.2. They indicated that they believed that joined-up working with infection control was good practice to address the spread of infection and AMR. **Supporting guidelines**: **SACAR AM Framework:** Section 4.6			
1.3	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Respondents indicated that accessing the DIPC job description maybe difficult. However, the role of the DIPC in AMS has been stipulated in published guidelines **Supporting guidelines:** **H&SC (2008):** Criterion 1: Section1.1; p.10; Criterion 1: Section 1.3, p.16; **Healthcare associated infection: What else can the NHS do?:** Section 1.2, p.6; **SACAR AM Framework:** Section 4.6; **Winning Ways: Management and Organisations:** p.21			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
1.4	**No modifications were made to this question**	N/A	N/A
Rationale for retention: No concerns were raised by respondents about Q1.4. The role of the antimicrobial committee and their responsibility to the Drugs and Therapeutics Committee or the Medicines Management Committee has been stipulated in the SACAR Antimicrobial Framework (2007). **Supporting guidelines:** **Antimicrobial Prescribing Policy and Practice in Scotland (2005):** Key area 1: Recommendation 3(3.2), Recommendation 4(4.2) and Key area 2: Recommendation 5; **SACAR Antimicrobial Framework:** Section 4.5 ***Clostridium difficile:*** **How to deal with the problem:** Core guidance: Recommendation 4 (4.1); **Medicines Management in NHS Trusts:** Standard 4, p.4; Standard 30, p.15			
1.5	**Comprehension-inclusion/exclusion**	**Action:** change the word *'it'* to the phrase *'antimicrobial committee or equivalent'*	**Original question:** How often does it meet? (original question) **Modified question:** How often does the *'antimicrobial committee or equivalent'* meet?
Rationale for retention: Generally, respondents indicated that trusts should monitor the frequency of their antimicrobial committee meetings. However, they expressed concerns regarding the scoring of this question *(see section 3.6.5.4).* Investigations into the most appropriate ASAT weightings were recommended for further research in order to determine appropriate weighting for this question. **Supporting guidelines:** *(see Q1.4)*			
1.6	**Comprehension-inclusion/exclusion**	**Action:** change the word *'it'* to the phrase *'antimicrobial committee or equivalent'*	**Original question:** Does it have minutes or an action list? **Modified question:** Does the *'antimicrobial committee or equivalent'* have minutes or an action list?
Rationale for retention: Respondents indicated that it was good practice to produce minutes and agreed actions from each meeting. Also, they suggested that there should be systems in place to ensure that the generated actions are completed. **Supporting guidelines:** *(see Q1.4)*			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
1.7	**Comprehension-inclusion/exclusion**	**Action:** insert *'antimicrobial committee or equivalent'*	**Original question:** Where do the minutes or actions go? **Modified question:** Where do the minutes or actions go from *'antimicrobial committee or equivalent'* go?
Rationale for retention: Based on the recommendations from SACAR and other published guidelines, it was decided that the minutes and agreed actions should be fed back to committees such as the Drugs and Therapeutics Committee or the Medicines Management Committee. Also, respondents that the minutes and actions generated from meetings should be sent to other relevant committees such as infection control and the Drugs and Therapeutics committee. **Supporting guidelines:** *(see Q1.4)*			
1.8	**Comprehension - lexical**	**Action:** refer end-users to the Health and Social Care Act (2008) where it states that the production of an annual antimicrobial stewardship report is recommended. The report can be either a standalone report or part of an infection control report	**Original question:** Does the Trust Board including non-Exec directors receive an annual report pertaining to antimicrobial stewardship? There were no modifications made to Q1.8.
Rationale for retention: Respondents agreed that trust boards should receive a report on AMS-related activity within their hospitals. This report could either be a standalone report or part of an infection control report. The content of the reports would be dependent on the trust. **Supporting guidelines:** *(see Q1.4)* Additionally, the role of the trust board such ensuring compliance to the Health and Social Care Act was highlighted in the report 'Reducing HAIs in hospitals in England' published by the National Audit Office (NAO 2009)			
2.1	**Comprehension-inclusion/exclusion**	**Action:** insert *'that clearly states the overall principles of antimicrobial use?'* **Action:** insert a definition of *'antimicrobial policy'* in the glossary of ASAT v16	**Original question:** Is there an AM policy (overall principles for use) or section in another trust policy? **Modified question:** Does your trust have an antimicrobial policy which clearly states the overall principles of antimicrobial use?
Rationale for retention: NHS trusts should have an overarching antimicrobial policy which should be supported by antimicrobial guidelines for treatment and prophylaxis. **Supporting guidelines:** **Antimicrobial Prescribing Policy and Practice in Scotland (2005):** Key area 1: Recommedation 3 (3.3), Key area 5, Recommendation 18, Appendix 1 (1.1), **SACAR Antimicrobial Framework:** Section 4.1, Section 4.4; **Saving Lives:** Section 1, p.2			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
2.2	**Comprehension-inclusion/exclusion**	**Action:** insert a definition of *'antimicrobial formulary'* in the glossary of ASAT v16	No modifications were made to Q2.2 however this question was moved to Q2.16 under the sub-section called '**ANTIMICROBIAL FORMULARY'**
Rationale for retention: NHS trusts should have an antimicrobial formulary which stipulates which the drugs are unrestricted, restricted *(approval of a specialist is required)* or permitted for specific conditions. **Supporting guidelines:** **Antimicrobial Prescribing Policy and Practice in Scotland (2005):** Key area 1: Recommedation 3 (3.3), Key area 5, Recommendation 18, Appendix 1 (1.1); **SACAR Antimicrobial Framework:** Section 3.4;			
2.3	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Respondents generally agreed that there should be systems in place to control the entry of new antimicrobials however these systems maybe dependent on the hospital settings and resources available. **Supporting guidelines:** *(see Q2.2)*			
2.4	**Comprehension-inclusion/exclusion**	**Action:** insert a definition of *'system'* in the glossary of ASAT v16. This definition will be accompanied by examples of restrictive interventions.	No modifications were made to Q2.4 however this question was moved to Q2.18 under the sub-section called '**ANTIMICROBIAL FORMULARY'**
Rationale for retention: Respondents indicated that hospitals should have systems to restrict antimicrobials however they stated that hospitals used different restriction systems such as pharmacy codes and other pre-approval mechanisms. **Supporting guidelines: Antimicrobial Prescribing Policy and Practice in Scotland (2005):** Key area 1: Recommedation 3 (3.3), Key area 5, Recommendation 18, Appendix 1 (1.1); **SACAR Antimicrobial Framework:** Section 3.5 and 3.6			
2.5	**Comprehension-inclusion/exclusion**	**Action:** insert a definition of *'system'* in the glossary of ASAT v16. This definition will be accompanied by examples of unauthorised reporting.	No modifications were made to Q2.5 however this question was moved to Q2.20 under the sub-section called '**ANTIMICROBIAL FORMULARY'**
Rationale for retention: This question was written from the perspective that any unauthorised prescribing should be identified and reported. Trusts should have a dedicated reporting system. Any unauthorised prescribing of AMs should be reported to and followed up by the AMP, relevant clinical teams and antimicrobial stewardship committee (AMC). Action taken: include examples of unauthorised prescribing e.g. contrary to AM policy, treatment guidelines and reporting systems within the ASAT. **Supporting guidelines:** *(see Q2.4)*			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
2.6	**Comprehension-inclusion/exclusion**	**Action:** insert a definition *of 'common infections'* in the glossary of ASAT v16. End-users will be referred to the antimicrobial guideline template which was produced by SACAR and includes a list of common infections	No modifications were made to Q2.6 however this question was moved to Q2.7 under the sub-section called **'ANTIMICROBIAL GUIDELINES'**
Rationale for retention: Respondents indicated that antimicrobial treatment guidelines were an essential component of AMS so therefore Q2.6 was retained in the ASAT. **Supporting guidelines: SACAR Antimicrobial Framework:** Section 4.1			
2.7	**Comprehension-inclusion/exclusion**	**Action:** insert a definition of '*common procedures'* in the glossary of ASAT v16. End-users will be referred to the antimicrobial guideline template which was produced by SACAR and includes a list of common infections	No modifications were made to Q2.7 however this question was moved to Q2.8 under the sub-section called **'ANTIMICROBIAL GUIDELINES'**
Rationale for retention: Respondents indicated that antimicrobial prophylaxis guidelines were an essential component of AMS so therefore Q2.6 was retained in the ASAT. **Supporting guidelines: SACAR Antimicrobial Framework:** Section 4.3; ***Clostridium difficile*: How to deal with the problem:** Core guidance: Recommendation 4 (4.4)			
2.8	**Double-barrelled question** **Lack of question sensitivity**	**Action:** This question was split into three questions in order to increase question sensitivity	**Original question:** How frequently are 2.1, 2.2, 2.6 and 2.7 reviewed? **Modified questions:** How frequently is the antimicrobial policy reviewed? (moved to Q2.6) How frequently are the antimicrobial guidelines reviewed? (moved to Q2.15) Nb. This question covers both treatment and surgical prophylaxis guidelines How often is the antimicrobial formulary reviewed? (moved to Q2.21)

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
Rationale for retention: ***(Q2.8 cont'd)*** These documents should be constantly under review, that is, there are active documents. This question was placed in the ASAT as a prompt for the importance of reviewing these documents on a regular basis. There is currently no allowance in the ASAT to record for the individual frequencies of each document review. The process of the communication of guideline updates should be part of the antimicrobial management strategy. **Supporting guidelines: Health and Social Care Act (2008)** Criterion 9: Section N, p.30; **Antimicrobial Prescribing Policy and Practice in Scotland (2005):** Appendix 1 (1.4); **SACAR Antimicrobial Framework:** Section 4.3; ***Clostridium difficile*****: How to deal with the problem:** Core guidance: Recommendation 4 (4.4); **Medicines Management in NHS Trusts:** Standard 12, p.8.			
2.9	**Irrelevant key concepts or questions**	**Action:** Remove question from ASAT v15a. This question was not applicable to NHS Trusts as they have electronically-based antimicrobial policies and guidelines	**Original question:** Is there document or version control for all policies or guidelines? **Modified question:** Not applicable (question deleted from ASAT v15a)
Rationale for deletion: Most NHS trusts used electronic guidelines and policies which were accessible via their trust intranet sites so therefore this question was redundant.			
2.10	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Respondents indicated that networked computers significantly improved the accessibility of antimicrobial guidelines in their NHS trusts. **Supporting guidelines: SACAR Antimicrobial Framework:** Section 4.1; **Saving Lives:** Section 1, p.2;			
2.11	**Irrelevant key concepts or questions**	**Action:** Insert the words *'or electronic'*	**Original question:** Is an easily accessible printed summary available to all wards and prescribers (e.g. pocket guide)? **Modified question:** Is an easily accessible printed or electronic summary available to all wards and prescribers e.g. pocket guide?
Rationale for retention: Respondents indicated that accessibility to guidelines was essential to improving compliance to guidelines in their hospitals which was improved by pocket guides and PDAs. **Supporting guidelines:** ***Clostridium difficile*****: How to deal with the problem:** Core guidance: Recommendation 4 (4.4); **Medicines Management in NHS Trusts:** Standard 12, p.8			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
2.12	**Comprehension - lexical**	**Action:** This question was reworded	**Original question:** Is selection for the guidelines informed by local microbiological sensitivity patterns? **Modified questions:** Is antimicrobial choice informed by local sensitivity patterns? This question was included in the sub-section called **ANTIMICROBIAL GUIDELINES** and moved to Q2.10
Rationale for retention: Generally, respondents indicated that this is an area of AMS that is weak in their hospitals and agreed that Q2.12 should remain in the ASAT. **Supporting guidelines: SACAR Antimicrobial Framework:** Section 3.5; **Medicines Management in NHS Trusts:** Standard 12, p.8			
2.13	**Double-barrelled question**	**Action:** This question was split into two questions in order to increase question sensitivity	**Original question:** Does the Microbiology Laboratory use selective reporting of results in line with formulary choices? **Modified questions:** (a) Does the microbiology laboratory use selective reporting of results? (b) Are these results in line with formulary choices?
Rationale for retention: Generally, respondents indicated that this is an area of AMS that is currently under-developed in their hospitals and agreed that Q2.13 should remain in the ASAT. They suggested that hospitals should ensure that utilise selective reporting of results in their ASPs. **Supporting guidelines: The Health and Social Care Act 2008:** Criterion 9: Section l, p.29; **SACAR Antimicrobial Framework:** Section 3.4; ***Clostridium difficile:* How to deal with the problem**: Core guidance: Recommendation 4 (4.4)			
2.14	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Respondents indicated that they would record the indication prior to prescribing antimicrobials but queried the weighting of the response options for Q2.14. **Supporting guidelines: The Health and Social Care Act 2008:** Criterion 9: Section l, p.29; ***Clostridium difficile:* How to deal with the problem**: Core guidance: Recommendation 4 (4.4); **Medicines Management in NHS Trusts:** Standard 12, p.8			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
2.15	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Respondents indicated that in most instances, course length or review date is recorded on the prescription chart at the time of prescribing in their hospitals. **Supporting guidelines: SACAR Antimicrobial Framework:** Section 4.3; ***Clostridium difficile:*** **How to deal with the problem**: Core guidance: Recommendation 4 (4.4)			
2.16	**Information retrieval**	**Action:** Remove the example 'Saving Lives' (outdated) and reword question	**Original question:** Does the AM policy stipulate that prescriptions be reviewed in line with *'Saving Lives'*? **Modified question:** Does the *Antimicrobial Policy** stipulate how often prescriptions should be reviewed? This question was included in the sub-section called **ANTIMCROBIAL POLICY** and moved to Q2.4
Rationale for retention: Prescription review was frequent in hospitals however the frequency was dependent on what their antimicrobial guidelines stipulated. **Supporting guidelines: Saving Lives:** Section 3, p.2; **Optimising the clinical use of antimicrobials:** Section (Local antibiotic policies)			
2.17	**No modifications were made to this question**	N/A	N/A
Rationale for retention: De-escalation of antimicrobial therapy was commonly practiced in hospitals and respondents indicated that this question was easy to answer. **Supporting guidelines:** *(see Q2.16)*			
2.18	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Each respondent indicated that their hospital has IV to oral switch guidelines**.** **Supporting guidelines:** *(see Q2.16)*			
2.19	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Generally, respondents indicated that durations are specified in their antimicrobial guidelines but in some instances they can conflict with clinical microbiology recommendations. **Supporting guidelines: Saving Lives:** Section 3, p.2; **Optimising the clinical use of antimicrobials:** Section (Local antibiotic policies); ***Clostridium difficile:*** **How to deal with the problem:** Core guidance: Recommendation 4 (4.2, 4.3)			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
2.20	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Each respondent indicated that guidance on choice, dose, route and IV switch for each indication is stipulated in antimicrobial guidelines. However, dosing for paediatrics is age-dependent. **Supporting guidelines:** **Saving Lives:** Section 3, p.2; **Optimising the clinical use of antimicrobials:** Section (Local antibiotic policies)			
2.21	**Comprehension-inclusion/exclusion**	**Action:** a definition of *'antimicrobial ward rounds'* will be added to the glossary of ASAT v16	This question was moved to Q2.22 as it did not fit into the sub-sections in Domain 2
Rationale for retention: Most respondents indicated that antimicrobial ward rounds were conducted in their hospitals however they may be more frequent in critical care areas than general wards. **Supporting guidelines:** *(see Q2.20)*			
2.22	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Most respondents indicated that they had access to clinical microbiologists in core working hours and there were working on establishing a 24-hour service in their hospitals. **Supporting guidelines:** **SACAR Antimicrobial Framework:** Section 4.7; ***Clostridium difficile:*** **How to deal with the problem:** Core guidance: Recommendation 4 (4.11)			
3.1	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Respondents indicated that their hospitals provide guidance on the management of allergies however the guidance was generally targeted at penicillin allergy management. Other respondents indicated that their guidance would be included in their hospitals' anaphylaxis policies. **Supporting guidelines:** **SACAR Antimicrobial Framework:** Section 3.2; **The Best Medicine:** Appendix B: Recommendations checklist for NHS trusts (Appendix B: Section 10a)			
3.2	**Lack of question sensitivity**	**Action:** add an example of IV administration guidance to Q3.2	**Original question:** Is there guidance on administration of IV AMs? **Modified question:** Is there guidance on administration of IV antimicrobials e.g. UCL guidelines
Rationale for retention: Respondents indicated that their hospitals had guidance on IV administration for all medicines including antimicrobials however these guidelines were not trust-specific and were based on the UCL Hospitals Injectable Drug Administration Guide. **Supporting guidelines:** (see Q3.2)			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
3.3 **3.4**	**Question duplication**	**Action:** merge Q3.3 and Q3.4	**Original questions:** **Q3.3** Is there guidance on dosing optimisation for AMs with a narrow therapeutic index? **Q3.4** Is there guidance on TDM for high risk AMs? **Modified question:** Is there guidance on dosing optimisation for antimicrobials with a narrow therapeutic index e.g. guidance on *Therapeutic Drug Monitoring** for high risk patients?
Rationale for retention: Most respondents indicated that their hospitals had pharmacokinetics services which would provide advice on dose optimisation for antimicrobials such as gentamicin and vancomycin. **Supporting guidelines:** N/A			
3.5	**Comprehension - lexical**	**Action:** reword question Q3.5	**Original question:** Is the safety of AMs linked to incident reporting with feedback and action plans? **Modified question:** Is there a system for recording and reporting antimicrobial incidents?
Rationale for retention: Some respondents indicated that their hospitals had incident reporting systems but there were not specific to antimicrobial incidents. They agreed that antimicrobial incidents should be reported to relevant staff groups and reviewed as part of the education strategy for the antimicrobial therapy. **Supporting guidelines:** N/A			
3.6	**Comprehension - lexical**	**Action:** reword question Q3.6	**Original question:** Are incident reports of AM usage fed back to the AM committee or other group? **Modified question:** Are antimicrobial-related incidents fed back to the antimicrobial committee or other group?

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
4.1	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Most respondents indicated that they had an active antimicrobial audit programme within their hospitals and they conducted point prevalence audits at least twice a year. **Supporting guidelines: The Health and Social Care Act (2008):** Criterion 10: Section 10.1, p.36; Healthcare associated infection: What else can the NHS do?: Section 2, p.6; Section 4, p.7; **SACAR Antimicrobial Framework:** Section 4.1, Section 4.3 and Section 5.4; **Clostridium difficile: How to deal with the problem:** Core guidance: Recommendation 4 (4.9); **Saving Lives:** Section 1, p.2			
4.2	**Comprehension - lexical**	**Action:** change *'antimicrobial prescribing policy*' to *antimicrobial policy'*	**Original question:** Is compliance with AM Prescribing Policy audited and fed back in each specialty at least once a year? **Modified question:** Is compliance with antimicrobial policy audited and fed back in each specialty at least once a year?
Rationale for retention: Each respondent indicated that they audited their prescribing policies at least annually however the results may not be fed back to each specialty within the hospitals. **Supporting guidelines: SACAR Antimicrobial Framework:** Section 4.1, Section 4.3 and Section 5.4; **Saving Lives:** Section 1, p.2			
4.3	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Respondents indicated that they may routinely audit antimicrobial restriction systems however they would identify non-compliance to restriction systems by other internal strategies. They suggested that auditing the effectiveness of restriction systems would be good practice. **Supporting guidelines: SACAR Antimicrobial Framework:** Section 4.1, Section 4.3 and Section 5.4; **Saving Lives:** Section 1, p.2			
4.4	**Question duplication**	**Action:** a definition for *'antimicrobial guidelines'* will be added to the glossary of ASAT v16 and delete the word *'adherence'* and replace with *'compliance'.* Delete the word *'pertinent'*	**Original question:** Is adherence to pertinent treatment guidelines audited in each specialty and fed back at least once a year? **Modified question:** Is compliance to treatment guidelines audited in each specialty and fed back at least once a year?
Rationale for retention: Each respondent indicated that they audited antimicrobial treatment guidelines however the entire guideline may not be audited on a regular basis. **Supporting guidelines:** *(see Q4.3)*			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
4.5	**Lack of question sensitivity**	**Action:** delete the word *'adherence'* and replace with *'compliance*.' Delete the word *'pertinent'*	**Original question:** Is adherence to pertinent surgical prophylaxis guidelines audited in each specialty and fed back at least once a year? **Modified question:** Is compliance to surgical prophylaxis guidelines audited in each specialty and fed back at least once a year?
Rationale for retention: Most respondents indicated that they audited their surgical prophylaxis guidelines as part of their annual audit programme. **Supporting guidelines:** *(see Q4.3)*			
4.6	**Lack of question sensitivity**	**Action:** delete the word *'adherence'* and replace with *'compliance'*	**Original question:** Is adherence to IV to Oral switch guidelines audited and fed back at least once a year? **Modified question:** Is compliance to IV to Oral switch guidelines audited and fed back at least once a year?
Rationale for retention: Most respondents indicated that they did routinely audit their IV to oral switch guidelines because it would be an labour intensive exercise however they will endeavour to audit these guidelines in the future. **Supporting guidelines:** *(see Q4.3)*			
4.7	**Lack of question sensitivity**	**Action:** the phrase *'with a narrow therapeutic index'* was removed from Q4.7 and delete the word *'adherence'* and replace with *'compliance'*	**Original question:** Is adherence to dosing and TDM guidelines for AMs with a narrow therapeutic index audited in each specialty and fed back at least once a year? **Modified question:** Is compliance to dosing and therapeutic drug monitoring (TDM) guidelines for antimicrobials audited in each specialty and fed back at least once a year?
Rationale for retention: Some respondents indicated that they audited TDM guidelines but it was not done on frequent basis. **Supporting guidelines:** *(see Q4.3)*			
4.8	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Most respondents indicated that they monitored antimicrobial consumption on a monthly basis however it may be difficult for paediatric wards and hospitals **Supporting guidelines:** **SACAR Antimicrobial Framework:** Section 5.1, Section 5.2			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
4.9	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Regular feedback to both clinical specialties and directorates on antimicrobial consumption was conducted by respondents. However, they indicated that their current systems for reporting consumption require improvement. **Supporting guidelines: SACAR Antimicrobial Framework:** Section 5.1			
4.10	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Most respondents indicated that they did not record attendance at audit meetings on a regular basis. However, it was felt that it would be good practice to monitor which staff groups attend meetings. **Supporting guidelines:** N/A			
4.11	**Double-barrelled question** **Lack of question sensitivity**	**Action:** this question will be split into two questions in order to improve question sensitivity	**Original question:** Are there action plans agreed and recorded and shared with the AM committee? **Modified questions:** a. Are there action plans agreed for each antimicrobial audit? b. Does the *antimicrobial committee** monitor the completion of actions generated from antimicrobial audits?
Rationale for retention: Most respondents indicated that they would feedback action plans to the antimicrobial committee and in instances where poor performance has been identified, an improvement notice would be sent to the relevant clinical specialty. **Supporting guidelines: SACAR Antimicrobial Framework:** Section 5.4; **The Best Medicine:** Appendix B: Recommendations checklist for NHS trusts (Appendix B: Section 10c)			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
5.1	**Comprehension-inclusion/exclusion**	**Action:** reword question in order to clarify that this question refers to key staff groups that are involved in antimicrobial stewardship	**Original question:** Is there an AM Education and Training strategy? **Modified question:** Is there an *antimicrobial education and training strategy** which is targeted at the key staff groups that are involved in antimicrobial prescribing?
Rationale for retention: Respondents indicated that the content of education and training strategies may vary between NHS trusts. Also, they highlighted that in the absence of national guidance or nationally accredited education on antimicrobial prescribing they would like guidance on the educational requirements for antimicrobial prescribers and other staff groups involved in antimicrobial therapy. **Supporting guidelines:** **The Health and Social Care Act (2008):** Criterion 10: Section 10.1, p.36; **SACAR Antimicrobial Framework**: Section 4.4,Section 6.1, Section 6.2; **Medicines Management in NHS Trusts:** Standard 26, p.13			
5.2	**Comprehension-inclusion/exclusion** **Irrelevant key concepts or questions**	**Action:** remove the word *'printed'* and *'AM prescribing'* and also reword Q5.2	**Original question:** Do all AM prescribers receive printed information about AM prescribing, formulary and guidelines at induction? **Modified question:** Are all antimicrobial prescribers given information about how to access a*ntimicrobial guidelines** and the *antimicrobial formulary** at induction?
Rationale for retention: Each respondent indicated that antimicrobial prescribers are signposted to antimicrobial guidelines and formularies as part of their induction procedures. **Supporting guidelines:** **SACAR Antimicrobial Framework**: Section 6.2			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
5.3	**Comprehension-inclusion/exclusion** **Irrelevant key concepts or questions**	**Action:** remove the word *'printed'* and *'AM prescribing' and also* reword question	**Original question:** Do all pharmacists receive printed information about AM prescribing, formulary and guidelines at induction? **Modified question:** Are all pharmacists given information about how to access *antimicrobial guidelines** and the *antimicrobial formulary** at induction?
Rationale for retention: Antimicrobial prescribers were signposted to the location of the antimicrobial guidelines and formularies at induction. They would not receive printed copies because these documents were accessible via the trust intranet sites. **Supporting guidelines:** *(see Q5.2)*			
5.4	**Comprehension-inclusion/exclusion**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'*	**Original question:** Is an annual update in safe and effective AM prescribing mandated for all prescribers? **Modified question:** Is an annual update in optimal antimicrobial prescribing mandated for all prescribers?
Rationale for retention: Most respondents indicated that updates on safe and effective prescribing were available for antimicrobial prescribers and pharmacists. However, these updates varied from ad-hoc training sessions to formalised educational sessions. Also, respondents indicated that they would like they would like to extent education to senior clinical staff involved in antimicrobial therapy. **Supporting guidelines:** **SACAR Antimicrobial Framework**: Section 6.2, **Medicine Matters:** Section 12			
5.5	**Comprehension-inclusion/exclusion**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'*	**Original question:** Is an annual update in safe and effective AM prescribing available for all prescribers? **Modified question:** Is an annual update in optimal antimicrobial prescribing available for all prescribers?
Rationale for retention: *(see Q5.4)* **Supporting guidelines:** *(see Q5.4)*			

Rationale for modification(s)		Recommended adjustments	Question modification(s)
5.6	**Comprehension-inclusion/exclusion**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'*	**Original question:** Is an annual update in safe and effective AM prescribing mandated for all pharmacists? **Modified question:** Is an annual update in optimal antimicrobial prescribing mandated for all pharmacists?
Rationale for retention: *(see Q5.4)* **Supporting guidelines:** *(see Q5.4)*			
5.7	**Comprehension-inclusion/exclusion**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'*	**Original question:** Is an annual update in safe and effective AM prescribing available for all pharmacists? **Modified question:** Is an annual update in optimal antimicrobial prescribing available for all pharmacists?
Rationale for retention: *(see Q5.4)* **Supporting guidelines:** *(see Q5.4)*			
5.8	**Comprehension-inclusion/exclusion**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'*	**Original question:** Is an annual update in safe and effective AM prescribing mandated for all staff who administer AMs? **Modified question:** Is an annual update in optimal antimicrobial prescribing mandated for all staff who administer AMs?
Rationale for retention: Respondents indicated that nursing staff would receive training in medicines management but it generally was not specific to antimicrobials. They indicated that these staff should receive education on antimicrobial therapy because they could identify antimicrobial prescription errors. **Supporting guidelines:** *(see Q5.4)*and **SACAR Antimicrobial Framework**: Section 6.1			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
5.9	**Comprehension-inclusion/exclusion**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'*	**Original question:** Is an annual update in safe and effective AM prescribing available for all staff who administer AMs? **Modified question:** Is an annual update in optimal antimicrobial prescribing available for all staff who administer AMs?
Rationale for retention: *(see Q5.8)* **Supporting guidelines:** *(see Q5.4)* and **SACAR Antimicrobial Framework**: Section 6.1			
5.10	**Question duplication**	**Action:** This question was deleted from ASAT v15a as it was viewed as a duplicate of Q5.2	**Original question:** Do all staff who prescribe AMs receive annual training in safe and optimal use? **Modified question:** Not applicable (question deleted from ASATv15a
5.11	**Question duplication** **Information retrieval** **Judgment/Decision** **Response formatting**	**Action:** This question was deleted from ASAT v15a as it was viewed as a duplicate of Q5.8 and Q5.9	**Original question:** Do all staff who administer AMs receive annual training in safe and optimal use? **Modified question:** Not applicable (question deleted from ASATv15a
5.12	**Question duplication** **Irrelevant key concepts or questions**	**Action:** This question was deleted from ASAT v15a as it was viewed as a duplicate of Q5.6 and Q5.7	**Original question:** Do all staff who dispense AMs receive annual training in safe and optimal use? **Modified question:** Not applicable (question deleted from ASATv15a

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
5.13	**Comprehension-inclusion/exclusion** **Information retrieval**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'* and split question into two questions which measure attendance at induction and continuing education.	**Original question:** What proportion of Foundation Year doctors attend training on safe and effective prescribing? **Modified question:** What proportion of Foundation Year doctors attend training on optimal antimicrobial prescribing? c. At induction d. Continuing education
Rationale for retention: Each respondent indicated that antimicrobial prescribing is part of the mandatory training programme for Foundation Year doctors therefore they would report 100% attendance in response to Q5.13. **Supporting guidelines:** *(see Q5.4)*			
5.14	**Comprehension-inclusion/exclusion** **Response formatting**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'* and split question into two questions which measure attendance at induction and continuing education	**Original question:** What proportion of registrars or specialist trainees attend training on safe and effective prescribing? **Modified question:** What proportion of registrars or specialist trainees attend training on optimal antimicrobial prescribing? c. At induction d. Continuing education
Rationale for retention: Respondents indicated that training is mandatory on induction but not part of their continuing education programme. **Supporting guidelines:** *(see Q5.4)*			
5.15	**Comprehension-inclusion/exclusion** **Information retrieval** **Response formatting**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'* and split question into two questions which measure attendance at induction and continuing education	**Original question:** What proportion of consultants attend training on safe and effective prescribing? **Modified question:** What proportion of consultants attend training on optimal antimicrobial prescribing? a. At induction b. Continuing education
Rationale for retention: Most respondents indicated that consultant grade staff did not receive training on antimicrobial prescribing so therefore this would be a good question to ask trusts because it could highlight the need for continuing education on antimicrobials. **Supporting guidelines:** *(see Q5.4)*			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
5.16	**Comprehension-inclusion/exclusion** **Information retrieval** **Judgment/Decision** **Response formatting**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'* and split question into two questions which measure attendance at induction and continuing education	**Original question:** What proportion of NMPs attend training on safe and effective prescribing? **Modified question:** What proportion of non-medical prescribers (NMPs) attend training on optimal antimicrobial prescribing? a. At induction b. Continuing education
Rationale for retention: Respondents indicated that NMPs were not routinely targeted for specific antimicrobial prescribing training however they highlighted that this is an issue which they would like to address in the future. **Supporting guidelines:** *(see Q5.4)* and also **Building a safer NHS for patients (2004)**: Page 144, (reducing the risks through education and training)			
5.17	**Comprehension-inclusion/exclusion** **Irrelevant key concepts or questions**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'* and split question into two questions which measure attendance at induction and continuing education	**Original question:** What proportion of staff who administer AMs attend training on safe and effective prescribing? **Modified question:** What proportion of staff who administer AMs attend training on optimal antimicrobial prescribing? a. At induction b. Continuing education
Rationale for retention: *(see Q5.16)* **Supporting guidelines:** *(see Q5.4),* **Building a safer NHS for patients (2004)**: Page 144, (reducing the risks through education and training), and **SACAR Antimicrobial Framework**: Section 6.1			
5.18	**Comprehension-inclusion/exclusion**	**Action:** remove the phrase '*safe and effective'* and replace with *'optimal'* and split question into two questions which measure attendance at induction and continuing education	**Original question:** What proportion of clinical pharmacists or technicians attend training on safe and effective prescribing? **Modified question:** What proportion of clinical pharmacists or technicians attend training on optimal antimicrobial prescribing? a. At induction b. Continuing education
Rationale for retention: Respondents indicated that training is mandatory at induction and continuing education may be conducted on an ad-hoc basis. They indicated that they would like to have a formal education programme in place for pharmacy staff but it can be time-consuming developing and delivering education across the trust. **Supporting guidelines:** **The Best Medicine:** Appendix B: Section 4 (a) to (d); **Standards of proficiency for nurses and midwives prescribers:** Standard 11			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
6.1	**Question duplication**	**Action:** the phrase *'within your department'* will be added to distinguish between Q6.1 and Q6.2	**Original question:** Is there a substantive AMP post in place? **Modified question:** Is there a substantive *antimicrobial pharmacist** post in place within your department?
Rationale for retention: Antimicrobial pharmacists were viewed themselves as essential to successful hospital-based ASPs because the ASP lead should have specialist training in antimicrobial therapy. **Supporting guidelines:** **Saving Lives:** Section 2, p.2; ***Clostridium difficile:*** **How to deal with the problem:** Core guidance: Recommendation 4 (4.1); **SACAR Antimicrobial Framework:** Section 4.7; **Medicines Management in NHS Trusts:** Standard 8, p.6, Standard 16, p.8			
6.2	**Question duplication**	**Action:** the word *'actively'* will be added to Q6.2 to distinguish between Q6.1 and Q6.2	**Original question:** Is there an AMP in post or in the process of recruitment? **Modified question:** Is there an *antimicrobial pharmacist** actively in post or in the process of recruitment?
Rationale for retention: *(see Q6.1)* **Supporting guidelines:** *(see Q6.1)*			
6.3	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Most respondents indicated that maintaining staff who are dedicated to antimicrobial duties is becoming increasing difficult due to budgetary constraints. However, they do try to ensure that antimicrobial duties are adequately covered by pharmacy staff. **Supporting guidelines:** **SACAR Antimicrobial Framework:** Section 4.7			
6.4	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Respondents agreed that antimicrobial pharmacists should be experienced in antimicrobial management but some queried the relevance of having greater than 3 years experience. **Supporting guidelines:** *(see Q6.1)*			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
6.5	**Lack of question sensitivity**	**Action:** question reworded and also an example of the qualifications which are targeted by this question	**Original question:** Does the lead AMP have a higher qualification higher than first degree (e.g. Diploma/MSc)? **Modified question:** Does the lead *antimicrobial pharmacist** have specialist training in infection management/antimicrobial use (e.g. MSc in Infection Management)?
Rationale for retention: Respondents indicated that they all had a qualification which was higher than a first degree such as a postgraduate diploma in Clinical Pharmacy. **Supporting guidelines:** *(see Q6.1)* and also **The Best Medicine:** Appendix B: Section 4 (a) to (d)			
6.6	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Respondents agreed that antimicrobial pharmacists should have specialised training in antimicrobial therapy. However, at the time of the study, there were not any specialised training available and sometimes obtaining study leave to attend training can be difficult. **Supporting guidelines:** *(see Q6.1)* and also **The Best Medicine:** Appendix B: Section 4 (a) to (d)			
6.7	**Question duplication**	**Action:** this question will be merged with Q6.7 and Q6.8 to improve question sensitivity and also the phrase *'relating to the antimicrobial strategy for the trust'* will be added	**Original question:** Does the AMP have written objectives within the last year? **Modified question:** Does the lead *antimicrobial pharmacist** have written objectives and a Personal Development Plan relating to the antimicrobial strategy for the trust?
6.8	**Question duplication**	**Action:** (see Q6.7)	**Original question:** Has the AMP have a PDP within the last year? **Modified question:** (see Q6.7)
Rationale for retention: Respondents indicated that they agreed that antimicrobial pharmacists should have written objectives and a PDP which related to the management of antimicrobials in hospitals. **Supporting guidelines:** *see Q6.1 and Q6.6*			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
6.9	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Respondents indicated that antimicrobial pharmacists should have an annual appraisal in order to ensure that they are meeting the objectives in their PDPs. **Supporting guidelines:** *see Q6.1 and Q6.6*			
6.10	**No modifications were made to this question**	N/A	N/A
Rationale for retention: *(see Q6.6)* **Supporting guidelines:** *(see Q6.1 and Q6.6)*			
7.1	**No modifications were made to this question**	N/A	N/A
Rationale for retention: Most respondents indicated that they may not have a policy specifically for patient information given to patients who are on antimicrobials because this may be incorporated in the trust's medicines information policy. **Supporting guidelines: National Standards, Local Action:** Core Standard C16, p.32; **A vision for pharmacy in the new NHS:** Section 4: (4.1) Hospital pharmacy; **General Pharmaceutical Council - Standards for Conduct, Ethics and Performance:** Section 4			
7.2	**Response formatting** **Reduction in response error**	**Action:** the word 'are' which required a 'yes' or 'no' response will be changed to *'how many'* which is applicable to determine the proportions required to answer the question**.** Also *'(> 80% of the time)'* was deleted from the question.	**Original question:** Are patients or their legal guardians (> 80% of the time) informed that they have been prescribed an antimicrobial and the reason why an antimicrobial is necessary? **Modified question:** How many patients or their legal guardians are informed that they have been prescribed an antimicrobial and the reason why an antimicrobial is necessary?
Rationale for retention: Antimicrobial counselling to patients was identified as good practice by respondents and that they would regularly counsel their patients about antimicrobial chemotherapy as part of their professional practice. However, they indicated that it would be difficult to measure. **Supporting guidelines:** *(see Q7.1)*			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
7.3	**Response formatting** **Reduction in response error**	**Action:** the word 'are' which required a 'yes' or 'no' response will be changed to *'how many'* which is applicable to determine the proportions required to answer the question**.**	**Original question:** Are patients or their legal guardians usually informed of the risks and side effects associated with antimicrobial treatment? **Modified question:** How many patients or their legal guardians are usually informed of the risks and side effects associated with antimicrobial treatment?
Rationale for retention: *(see Q7.2)* **Supporting guidelines:** *(see Q7.1)*			
7.4	**Response formatting** **Reduction in response error**	**Action:** the word 'are' which required a 'yes' or 'no' response will be changed to *'how many'* which is applicable to determine the proportions required to answer the question**.**	**Original question:** Are patients or their legal guardians usually informed that they have been prescribed an antimicrobial to take home and the reason why an antimicrobial is necessary? **Modified question:** How many patients or their legal guardians usually are informed that they have been prescribed an antimicrobial to take home and the reason why an antimicrobial is necessary?
Rationale for retention: *(see Q7.2)* **Supporting guidelines:** *(see Q7.1)*			
7.5	**Response formatting** **Reduction in response error**	**Action:** the word 'are' which required a 'yes' or 'no' response will be changed to *'how many'* which is applicable to determine the proportions required to answer the question**.**	**Original question:** Are patients or their legal guardians usually informed of the course length and the importance of finishing the course? **Modified question:** How many patients or their legal guardians are usually informed of the course length and the importance of finishing the course?
Rationale for retention: *(see Q7.2)* **Supporting guidelines:** *(see Q7.1)*			

Question	Rationale for modification(s)	Recommended adjustments	Question modification(s)
7.6	**Response formatting** **Reduction in response error**	**Action:** the word 'are' which required a 'yes' or 'no' response will be changed to *'how many'* which is applicable to determine the proportions required to answer the question**.**	**Original question:** Are patients or their legal guardians usually informed about possible side effects of antimicrobials and what to do if side effects develop at home? **Modified question:** How many patients or their legal guardians usually informed about possible side effects of antimicrobials and what to do if side effects develop at home?
Rationale for retention: *(see Q7.2)* **Supporting guidelines:** *(see Q7.1)*			
7.7	**Question duplication**	**Action:** this question was deleted from ASAT v15a as it was viewed as a duplication of Q7.1 to Q7.6	**Original question:** Has there been an explanation on the AM given to the patient? **Modified question:** question deleted from ASAT 15a

APPENDIX XXV - Modifications Table (ASAT v16 to ASAT v17)

No	Rationale for modification	Recommended adjustments
1	A new domain was inserted (see modification 6) into the ASAT so therefore the instruction section needed to be updated.	On page 1- **INTRODUCTION** The section which lists the sub-headings of the ASAT was updated to include the section for clinical microbiologists.
2	A biannual ASAT evaluation was viewed as too frequent as most NHS Trusts may have resources to conduct an annual evaluation. An annual evaluation may provide an accurate representation of a hospital's progress against the questions in the ASAT.	On page 2 - **HOW TO COMPLETE THE ASAT** The word *'biannual'* was deleted and replaced with *'annual'*.
3	The comparison of cumulative scores for NHS Trusts was viewed as a redundant statement as the scores from ASAT evaluation will be made publically available.	On page 2 - **HOW TO COMPLETE THE ASAT** The sentence *'NHS hospitals can compare their scores with the maximum cumulative scores for each domain'* was deleted from the ASAT.
4	Q2.23 which measures whether antimicrobial susceptibility results are reported in line with formulary choices was viewed as a clinical microbiology responsibility.	On page 5 - **Operational delivery of antimicrobial strategy (Domain 2)** Q2.23 was moved to Domain 7 (Clinical microbiologist) and has become Q7.6
5	Q4.8 which measures whether hospitals monitor antimicrobial consumption per activity and it was felt that the examples given was redundant.	On page 6 - **Clinical Governance and Audit (Domain 4)** The examples 'admissions or bed days' were removed from Q 4.8
6	The findings from the interviews and also the literature review supported the inclusion of a domain for clinical microbiologists. Also, of the proposed questions for this domain was *'Are clinical microbiologists involved in the development of antimicrobial formularies?'* However, respondents indicated that the antimicrobial formulary would be developed from antimicrobial guidelines so therefore this does not need to be a separate question. This question was removed from the domain 7.	Domain 7 for clinical microbiologists was added to the ASAT :- Q7.1 Is there a clinical microbiologist on your hospital's antimicrobial stewardship committee or equivalent? Q7.2 Are clinical microbiologists within your hospital involved in the development of antimicrobial policies and guidelines? Q7.3 Is the hospital actively involved in surveillance or monitoring of antimicrobial resistance trends? Q7.4 Are antimicrobial resistance trends used to inform the content of antimicrobial policies and guidelines? Q7.5 Are clinical microbiologists involved in antimicrobial ward rounds? Q7.6 Is advice from a clinical microbiologist or infectious disease physician available by phone?
7	START SMART and then FOCUS was published in November 2011 by the Department of Health	**Appendix 1** (ASAT v17) This publication was added to the Appendix of ASAT v17.

APPENDIX XXVI - Modifications Table (ASAT v17 to ASAT v18)

No	Modification	Rationale for adjustments
1	Replace *'2009'* with *'2012'*	On page 1- **INTRODUCTION** The evidence base has been updated since 2009 so therefore *'2009'* was substituted with *'2012'*.
2	Change *'see Appendix I'* to *'Appendix I - see page 13 to page 14'*	On page 1 -**INTRODUCTION** Appendix I which contains the policies, guidelines and reports which underpins the ASAT has been signposted.
3	Change *'NHS hospitals'* to *'NHS acute hospitals'*	On page 1 - **INTRODUCTION**
4	Change 'antimicrobial stewardship programmes' to ASPs	On page 1 - **INTRODUCTION** This term was previously abbreviated in the first paragraph of the introduction
5	Change *'It is envisaged that the ASAT could be used by antimicrobial pharmacists (AMPs)*'* to *'It is envisaged that the ASAT could be used by healthcare professionals involved in ASPs such as antimicrobial pharmacists'*	On page 1 - **INTRODUCTION** In order to promote a multidisciplinary approach to completing the ASAT, the phrase *'antimicrobial pharmacists'* was changed to '*healthcare professionals involved in ASPs such as antimicrobial pharmacists(AMPs)'*
6	Insert '*see page 15 to page 17' and glossary*	On page 1 - **INTRODUCTION** The glossary of terms used in ASAT v.18 has been signposted
7	Insert '*An interpretation of the cumulative scores (RAG Status) is provided on page 12'*	On page 2 - HOW TO COMPLETE THE ASAT An interpretation of the cumulative scores has been added to the ASAT so that NHS trusts can monitor their performance.
8	Q1.5 Change *'2= > quarterly'* to *'2 = greater than quarterly'* Change *'0= <quarterly'* to *'0 = less than quarterly'*	On page 3 - **ANTIMICROBIAL MANAGEMENT WITHIN THE TRUST** In order to clarify the response options for Q1.5 *'>'* and *'<'* were substituted with *'greater than'* and *'less than'* respectively
9	Q1.7 ▪ The abbreviations for the response options 'CG/IC/DTC' have been provided at the bottom of page 3 ▪ Change *'higher level'* to *'higher level e.g. Trust Board'*	On page 3 - **ANTIMICROBIAL MANAGEMENT WITHIN THE TRUST** ▪ This was done in order to clarify the meanings of 'CG/IC/DTC' for respondents. ▪ Trust Board was included as an example of higher level reporting
10	Q2.2: An additional response option *'0 = not stipulated in antimicrobial policy'* was added to provide an option for antimicrobial policies that do not stipulate that indication should be prescribed before antimicrobials are prescribed.	On page 4 - **OPERATIONAL DELIVERY OF ANTIMICROBIAL STEWARDSHIP STRATEGY** Prior to conducting the Rasch analysis and modelling Q2.2 had to be recoded because there was no option equating to '0'.

No	Modification	Rationale for adjustments
11	Q2.3 An additional response option *'0 = not stipulated in antimicrobial policy'* was added to provide an option for antimicrobial policies that do not stipulate that course length or review date is recorded on the prescription chart at the time of prescribing.	On page 4 - **OPERATIONAL DELIVERY OF ANTIMICROBIAL STEWARDSHIP STRATEGY** Prior to conducting the Rasch analysis and modelling Q2.3 had to be recoded because there was no option equating to '0'.
12	Q2.4 An additional response option *'0 = not stipulated in antimicrobial policy'* was added to provide an option for antimicrobial policies that do not stipulate that do not stipulate how often prescriptions should be reviewed.	On page 4 - **OPERATIONAL DELIVERY OF ANTIMICROBIAL STEWARDSHIP STRATEGY** Prior to conducting the Rasch analysis and modelling Q2.4 had to be recoded because there was no option equating to '0'.
13	Q2.6 An additional response option *'0= less than every two years'* was added to provide an option for antimicrobial policies which are reviewed less frequently than every two years	On page 4 - **OPERATIONAL DELIVERY OF ANTIMICROBIAL STEWARDSHIP STRATEGY** Prior to conducting the Rasch analysis and modelling Q2.6 had to be recoded because there was no option equating to '0'.
14	Q2.15 An additional response option '*0= less than every two years'* was added to provide an option for antimicrobial guidelines which are reviewed less frequently than every two years	On page 5 - **OPERATIONAL DELIVERY OF ANTIMICROBIAL STEWARDSHIP STRATEGY** Prior to conducting the Rasch analysis and modelling Q2.15 had to be recoded because there was no option equating to '0'.
15	Q2.21 An additional response option *'0= less than every two years'* was added to provide an option for antimicrobial formularies which are reviewed less frequently than every two years	On page 5 - **OPERATIONAL DELIVERY OF ANTIMICROBIAL STEWARDSHIP STRATEGY** Prior to conducting the Rasch analysis and modelling Q2.21 had to be recoded because there was no option equating to '0'.
16	Q2.22 ▪ Change *'>twice a week'* to '*greater than twice a week'* ▪ An additional response option *'0= less than weekly'* was added to provide an option for antimicrobial formularies which are reviewed less frequently than every two years	On page 5 - **OPERATIONAL DELIVERY OF ANTIMICROBIAL STEWARDSHIP STRATEGY** ▪ In order to clarify the response options for Q2.22 *'>'* was substituted with *'greater than'*. ▪ Prior to conducting the Rasch analysis and modelling Q2.22 had to be recoded because there was no option equating to '0'.

No	Modification	Rationale for adjustments
17	Q4.8 ▪ Change *'2 = < annually'* to '2 = *less than annually'* ▪ An additional response option *'0 = greater than annually'* was added to provide an option for trusts that may monitor their antimicrobial consumption less frequently than annually	On page 6 - **CLINICAL GOVERNANCE and AUDIT** In order to clarify the response options for Q4.8 *'<'* was substituted with *'less than'*. Prior to conducting the Rasch analysis and modelling Q4.8 had to be recoded because there was no option equating to '0'.
18	Q6.3 ▪ Change *'3 = >1.0'* to *'3 = greater than 1.0 WTE'* ▪ Change '*2 = 0.4'* to '*2 = 0.4 WTE'* ▪ Change *'1 = <0.4'* to *'1 = less than 0.4 WTE'* ▪ a response option of *'0 = none'* was added for trusts which may not have any dedicated pharmacy staff for antimicrobial duties.	On page 8 - **ANTIMICROBIAL PHARMACIST** These changes were made to clarify the response options for Q6.3. Prior to conducting the Rasch analysis and modelling Q6.3 had to be recoded because there was no option equating to '0'.
19	Q7.6 An additional response option *'0= not available*' was added to provide an option for trusts which may not have advice from a clinical microbiologist or an infectious disease physician available by phone	On page 9 - **CLINICAL MICROBIOLOGIST** Prior to conducting the Rasch analysis and modelling Q7.6 had to be recoded because there was no option equating to '0'.
20	A section for the scores obtained by NHS acute trusts has been added to each domain. A table has been added on page 14 for the overall cumulative scores obtained and also an interpretation of the ASAT scores has been added.	A section for the each domain score and overall ASAT scores was added so that ASAT users can add their scores and observe their performance over subsequent ASAT evaluations.
21	The glossary of ASAT v18 was put into alphabetical order	This was done in order to make it easier for respondents to locate the meanings of the terms or phrases used in ASAT v18

APPENDIX XXIX - NHS Trust statistics (Domain 1, 2, 4 and 5)

NHS TRUST STATISTICS - (Domain 1)

NHS trust	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT MNSQ
1	8	8	2.83	1.18	0.71	-0.30	0.29	-0.20
2	8	8	2.83	1.18	0.86	0.00	0.36	-0.10
3	9	8	4.31	1.89	**MAXIMUM MEASURE**			
4	6	8	0.75	0.95	0.36	-1.40	0.27	-1.10
5	8	8	2.83	1.18	1.41	0.80	0.86	0.40
6	9	8	4.31	1.89	**MAXIMUM MEASURE**			
7	8	7	4.25	1.90	**MAXIMUM MEASURE**			
8	7	8	1.68	1.00	0.42	-1.30	0.26	-0.50
9	7	8	1.68	1.00	1.41	0.90	0.99	0.40
10	7	8	1.68	1.00	1.05	0.30	0.61	0.00
11	8	8	2.83	1.18	0.86	0.00	0.36	-0.10
12	4	8	-0.88	0.89	0.82	-0.30	0.61	-0.20
13	9	8	4.31	1.89	**MAXIMUM MEASURE**			
14	7	8	1.68	1.00	0.42	-1.30	0.26	-0.50
15	8	8	2.83	1.18	0.71	-0.03	0.29	-0.20
16	8	8	2.83	1.18	0.86	0.00	0.36	-0.10
17	9	8	4.31	1.89	**MAXIMUM MEASURE**			
18	9	8	4.31	1.89	**MAXIMUM MEASURE**			
19	7	8	1.68	1.00	0.42	-1.30	0.26	-0.50
20	9	8	4.31	1.89	**MAXIMUM MEASURE**			
21	9	8	4.31	1.89	**MAXIMUM MEASURE**			
22	4	8	-0.88	0.89	1.49	1.20	1.13	0.40
23	8	8	2.83	1.18	0.86	0.00	0.36	-0.01
24	8	8	2.83	1.18	1.65	1.10	1.95	1.00
25	4	5	2.07	1.26	2.02	1.50	4.02	1.70
26	8	8	2.83	1.18	1.41	0.80	0.86	0.40
27	9	8	4.31	1.89	**MAXIMUM MEASURE**			
28	8	8	2.83	1.18	0.71	-0.30	0.29	-0.20
29	8	8	2.83	1.18	0.71	-0.30	0.29	-0.20
30	8	8	2.83	1.18	0.71	-0.30	0.29	-0.20
31	4	8	2.07	1.26	2.02	1.50	4.02	1.70
32	7	8	1.68	1.00	0.95	0.10	0.54	0.00
33	8	8	2.83	1.18	1.65	1.10	1.95	1.00
Mean	7.50	7.80	2.69	1.32	1.02	0.10	0.89	0.10
S.D	1.50	0.70	1.35	0.36	0.48	0.90	1.05	0.70

NHS TRUST STATISTICS - (Domain 2)

NHS trust	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT MNSQ
1	28	19	2.70	0.63	1.70	1.30	0.79	0.30
2	22	19	1.14	0.46	1.03	0.20	1.18	0.50
3	22	17	1.55	0.48	1.21	0.70	1.05	0.30
4	20	19	0.72	0.45	0.99	0.10	0.75	-0.40
5	25	18	2.21	0.57	0.86	-0.20	1.05	0.40
6	25	19	1.80	0.49	0.92	-0.10	1.30	0.60
7	14	19	-0.57	0.48	1.09	0.40	0.96	0.00
8	28	19	2.70	0.63	0.80	-0.20	0.58	0.10
9	28	19	2.70	0.63	0.92	0.00	0.64	0.20
10	25	19	1.80	0.49	0.91	-0.10	0.50	-0.40
11	30	19	3.83	0.92	0.87	0.10	1.03	0.50
12	30	19	3.83	0.92	0.95	0.20	6.54	2.30
13	26	19	2.06	0.52	0.70	-0.70	0.47	-0.30
14	25	19	1.80	0.49	1.58	1.50	0.95	0.20
15	26	19	2.06	0.52	0.48	-1.50	0.31	-0.70
16	31	19	5.05	1.31	0.18	-0.90	0.03	-1.00
17	25	19	1.80	0.49	0.74	-0.70	0.40	-0.60
18	23	19	1.35	0.46	0.38	-2.40	0.27	-1.30
19	24	19	1.57	0.48	1.08	0.30	0.68	-0.20
20	29	19	3.16	0.73	1.01	0.20	2.50	1.20
21	25	19	1.80	0.49	1.76	1.90	0.99	0.30
22	29	19	3.16	0.73	1.86	1.30	0.77	0.30
23	20	19	0.72	0.45	1.33	0.90	1.43	0.90
24	25	19	1.80	0.49	0.45	-1.90	0.29	-0.90
25	6	19	-2.51	0.70	0.69	-0.70	0.39	-0.40
26	21	19	0.93	0.45	0.79	-0.50	0.78	-0.20
27	25	19	1.80	0.49	1.28	0.90	1.87	1.10
28	25	19	1.80	0.49	0.92	-1.10	1.22	0.50
29	24	19	1.57	0.48	0.38	-2.40	0.33	-1.00
30	29	19	3.16	0.73	1.01	0.20	0.82	0.30
31	22	18	1.33	0.47	1.54	1.50	3.58	2.50
32	24	19	1.57	0.48	1.02	0.20	1.13	0.40
33	27	19	2.35	0.56	0.86	-0.20	1.01	0.40
Mean	24.50	18.80	1.90	0.58	0.89	0.00	1.11	0.20
S.D	4.70	0.60	1.30	0.18	0.39	1.00	1.17	0.80

NHS TRUST STATISTICS - (Domain 4)

NHS trust	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT MNSQ
1	12	12	2.91	1.08	1.21	0.50	1.42	0.70
2	9	12	1.02	0.65	0.69	-0.80	0.55	-0.60
3	6	12	0.18	0.62	0.84	-0.50	0.58	-1.00
4	8	12	0.61	0.62	0.84	-0.40	1.24	0.60
5	10	12	1.48	0.71	0.82	-0.30	0.55	-0.40
6	8	12	0.61	0.62	0.72	-0.80	0.65	-0.60
7	6	12	-0.12	0.61	0.76	-0.80	0.59	-1.00
8	9	12	1.02	0.65	0.69	-0.80	0.55	-0.60
9	5	12	-0.51	0.63	1.58	1.40	1.18	0.50
10	6	12	-0.12	0.61	1.17	0.60	0.92	0.00
11	10	12	1.48	0.71	0.67	-0.70	0.49	-0.50
12	2	12	-2.08	0.86	1.45	0.90	2.77	1.50
13	6	12	-0.12	0.61	0.85	-0.50	0.93	0.00
14	4	12	-0.94	0.68	1.26	0.70	1.16	0.50
15	8	12	0.61	0.62	0.82	-0.50	0.71	-0.50
16	13	12	4.22	1.86	**MAXIMUM MEASURE**			
17	9	12	1.02	0.65	1.37	1.00	1.74	1.20
18	11	12	2.05	0.82	1.06	0.30	0.80	0.20
19	7	12	0.24	0.61	1.06	0.30	0.93	0.00
20	8	12	0.61	0.62	1.29	0.90	1.23	0.60
21	5	12	-0.51	0.63	1.87	2.00	1.49	1.10
22	7	12	0.24	0.61	1.15	0.60	0.91	-0.10
23	4	12	-0.94	0.68	0.60	-0.90	0.52	-0.90
24	9	12	1.02	0.65	0.78	-0.50	0.67	-0.40
25	4	12	-0.94	0.68	0.83	-0.20	0.68	-0.50
26	1	12	-3.02	1.12	1.32	0.60	1.15	0.60
27	8	12	1.82	0.85	0.69	-0.50	0.46	-0.10
28	11	12	2.05	0.82	1.39	0.80	1.54	0.80
29	11	12	2.05	0.82	2.66	2.30	2.12	1.10
30	12	12	2.91	1.08	1.21	0.50	1.43	0.70
31	6	12	-0.12	0.61	0.95	-0.10	0.61	-1.00
32	5	12	-0.51	0.63	0.94	0.00	1.04	0.20
33	13	12	4.22	1.86	**MAXIMUM MEASURE**			
Mean	7.70	11.90	0.68	0.78	1.08	0.20	1.02	0.10
S.D	3.00	0.50	1.56	0.31	0.42	0.80	0.52	0.70

NHS TRUST STATISTICS (Domain 5)

NHS trust	Total score	Count	Measure	Model S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT MNSQ
1	45	22	2.25	0.56	0.74	-0.10	0.21	-0.40
2	23	22	0.07	0.25	0.53	-1.60	0.45	-1.30
3	7	22	-1.26	0.39	0.46	-0.90	0.25	-0.80
4	9	22	-1.00	0.34	1.86	1.50	1.24	0.60
5	21	22	-0.06	0.25	1.76	2.00	1.34	0.80
6	39	22	1.18	0.33	0.55	-0.80	0.65	-0.10
7	17	22	-0.32	0.26	0.58	-1.30	0.51	-1.00
8	18	22	-0.25	0.26	0.70	-0.80	0.95	0.10
9	8	22	-1.12	0.36	1.18	0.50	0.66	-0.10
10	14	22	-0.54	0.28	0.73	-0.60	0.44	-1.10
11	18	22	-0.25	0.26	0.83	-0.40	0.99	0.10
12	1	22	-3.79	1.20	1.81	1.00	1.56	0.80
13	5	22	-1.62	0.46	0.31	-1.20	0.20	-0.50
14	8	22	-1.12	0.36	1.69	1.20	1.02	0.30
15	17	22	-0.32	0.26	1.17	0.60	0.86	-1.10
16	5	22	-1.62	0.46	0.79	-0.10	0.19	-0.50
17	9	22	-1.00	0.34	0.81	-0.20	1.08	0.40
18	31	22	0.56	0.25	0.77	-0.77	0.66	-0.40
19	17	16	0.17	0.35	0.61	-0.80	0.50	-0.70
20	17	22	-0.32	0.26	0.97	0.00	1.18	0.50
21	17	22	-0.32	0.26	0.97	0.00	1.46	1.00
22	24	22	0.13	0.25	2.83	4.00	4.17	3.80
23	20	22	-0.12	0.25	0.89	-0.20	1.13	0.40
24	18	22	-0.25	0.26	1.44	1.20	1.21	0.60
25	8	22	-1.12	0.36	2.34	1.90	2.11	1.30
26	12	22	-0.70	0.30	0.74	-0.50	0.38	-1.10
27	12	16	-0.45	0.35	1.46	1.10	0.91	0.00
28	21	22	-0.60	0.25	0.51	-1.70	0.48	-1.20
29	15	22	-0.46	0.27	1.35	1.00	1.15	0.50
30	22	22	0.00	0.25	0.70	-0.90	0.73	-0.50
31	21	22	-0.60	0.25	0.87	-0.30	0.58	-0.90
32	5	22	-1.62	0.46	1.08	0.30	0.74	0.20
33	3	22	-2.20	0.64	0.44	-0.40	0.25	-0.30
Mean	16.00	21.60	-0.53	0.35	1.04	0.10	0.92	0.00
S.D	9.60	1.40	1.01	0.18	0.57	1.20	0.72	0.90